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CURRENT METHODOLOGIES OF IDENTIFYING
R&M PROBLEMS IN FIELDED
WEAPON SYSTEMS

THESIS

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Master of Science in Systems Management

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Preface

The purpose of study was to illustrate methodologies used to identify reliability and maintainability problems in fielded Air Force weapon systems. With the advent of R&M 2000, R&M issues are on the top of Air Force Commanders' agenda. This thesis will identify the different sources of information and organizations doing R&M work in the Air Force today. This study will be especially helpful to program managers new to R&M improvement programs as a guide to where to begin, what to look for, benefits to be gained, and who is doing what to improve R&M in Air Force weapon systems.

This study will give the new program manager an overall look at how the different organizations throughout the Air Force are identifying and priorizating R&M problems on fielded weapon systems. This study is only concerned with hardware problems and gives an example of how the use the Air Force Maintenance Data Collection System (MDC) to identify potential hardware R&M problems.

I could not have done this thesis without the help of my two academic advisers, Captain Clinton Campbell and Carroll Widenhouse. I am deeply indebted to them for their continuing patience and assistance during the research for this thesis. Finally, I wish to thank my wife Alice for her understanding and help in proofreading this work.

Jamison E. Murray

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Abstract

This thesis outlines methodologies used in the identification of reliability and maintainability problems in fielded Air Force weapon systems. The goal of the thesis was to provide program managers new to the R&M field an understanding of the terms, procedures, and organizations in the Air Force involved in solving R&M problems in fielded weapon systems. The study gives examples using the Pareto Principle and the Maintenance Data Collection System (MDC) to identify the top burners as far as maintenance action taken on fielded weapon systems.

The study examines how to use a product improvement working group (PIWG) to verify that the top burners identified with MDC are actually R&M problems that need to be worked. It also gives examples of successful R&M programs and the benefits that can be achieved with R&M improvements to fielded weapon systems.

This thesis can be used as a guide for new program managers in the search for R&M improvements to their weapon systems. By following the guidelines of this thesis, a new program manager will have a basic understanding of how organizations throughout the Air Force work together to identify R&M problems in fielded weapon systems.

CURRENT METHODOLOGIES OF IDENTIFYING R&M PROBLEMS IN FIELDED WEAPON SYSTEMS

I. Introduction

Objective

The subjects of reliability and maintainability (R&M) are of great interest in the Air Force today. The results of poor R&M are loss of warfighting capability and high weapon system operation and support costs; poorly designed systems wear out too soon, break often, and need frequent repairs (22:3). The major objective of improving R&M is to enhance the warfighting capability of our weapon systems. A lesser objective is to minimize the burden of owning and operating a weapon system. When reliability and maintainability are improved, weapon system failures are reduced, as are the need for spares and the number of required maintenance actions. Program managers need to realize the great return on investment and increases in warfighting capability that a well-executed reliability and maintainability improvement program can produce (8:29).

The Air Force must try to acheive and ensure optimum field performance. In this regard, the maintenance repair process has shifted from a "find and fix" mode of operation to one of identifying the root cause of errors and correcting the process. An example of this shift is the recent attention given to Electrostatic Discharge (ESD) awareness (23:22). Items were returning from the repair depots not in working order. After investigation of this problem, the cause of the failures was due to damaged components resulting from the effects of ESD. After these effects were realized, preventative measures have been instituted to prevent ESD damage to items being repaired.

The Air Force currently has five goals to be attained through accelerated improvements in R&M. These goals, known as R&M 2000 goals, in order of priority, are:

1. Increased Combat Capability;
2. Decreased Vunerability of combat support structure;
3. Decreased Mobility requirements per unit;
4. Decreased Manpower requirements per unit of output;
5. Decreased Cost (20:1).

Much is being done to help achieve these goals. Many organizations in the Air Force are involved. The laboratories address R&M issues for future applications, while system program offices (SPOs) integrate evolving technologies with improved R&M into new system acquisitions. The Air Logistics Centers focus on improving R&M on fielded systems, and headquarters staffs at all levels deal with R&M issues at every stage in a weapon system's life cycle.

Many R&M initiatives for new acquisitions are referenced in the literature. Initiatives mentioned include "Reliability-Centered Maintenance (RCM), Combined Environmental Reliability Testing (CERT), Joint Logistics Commanders' Initiatives, and a single-thread data system" (20:E-13). Initiatives in technology include Very High Speed Integrated Circuits (VHSIC), computer graphic techniques, fiber optics, and inspection technologies (20:E-13).

Much attention is being focused on new acquisitions like the Advanced Tactical Fighter (ATF) and the C-17. Considering R&M is very important in the initial stages of weapon system acquisition, but the R&M benefits of these new system will not be realized until some time in the future.

The Air Force must also focus attention on modification of existing weapon systems. During LOGTALK XII (8-9 Jan 85), the point was made that in the year 2000, 85% of Air Force weapon systems would have been designed and fielded prior to the new guidance on R&M (2:2). This statistic implies that new weapon systems designed and developed under the guidelines of R&M 2000 will not be available for a long time.

In order to meet the R&M 2000 goals, the Air Force needs to be aware that fielded weapon systems may benefit from modification to improve the R&M of these systems. Some initiatives are now being done. AFLC weapon system program managers have been charged to produce a system engineering baseline and to look for R&M and other support problems. The Air Force Logistics R&M program has focused AFSC's laboratories on supportability issues. The Productivity, Reliability, Availability, Maintainability (PRAM) office has been working for several years to help develop products that do the job better and cheaper (22:4).

The Air Force Logistics Command's R&M 2000 program is putting new emphasis on the importance of reliability and maintainability in modifications. No longer are planners limited to fractional advances in R&M. An educational process just beginning will demonstrate to the program managers and engineers the availability of quantum leaps in both reliability and maintainability in fielded weapon systems. Examples of R&M improvements include very high speed integrated circuit (VHSIC) technology, which is increasing the mean time between failures (MTBFs) of units from hundreds of hours to thousands of hours, and aircraft ring-laser gyros, which have MTBFs ten times that of a spinning-mass inertial gyro (9:57).

R&M improvements start with identifying and prioritizing current R&M problems on fielded weapon systems. The objective of this research is to provide methodologies used to identify reliability and maintainability problems in fielded Air Force weapon systems. This thesis gives the newly assigned program manager a basic look into the methodologies of identifying and prioritizing the "bad actors" of a weapon system or subsystem.

Problem Statement

The problem as stated by Albright in his article Base Level Reliability and Maintainability (R&M) Improvement Program is that "There is no system designed specifically to identify and correct R&M problems on already fielded USAF weapon systems" (2:2). The methods of selecting and managing potential modifications to existing Line Replaceable Units (LRU) or components may be difficult for new program managers to get a handle on. Program managers new to weapon system program offices, Air Logistics Centers, or Headquarters R&M shops may not have the experience necessary to identify R&M problems. Guidance is needed for new program managers working on weapon systems or subsystems on how to identify and select potential modification candidates on fielded LRUs or components to increase the system's R&M. This research focuses on the methodology of identifying and prioritizing R&M problems on fielded weapon systems

Background

Increased emphasis within the U.S. Air Force on R&M has directly impacted the major weapon system acquisition process. The Air Force is committed to improving warfighting capability by demanding accelerated R&M improvements in both new and fielded systems. The primary document initiating the focus on R&M is an action memorandum signed on 17 September 1984 by Chief of Staff, Gen Charles A Gabriel, and Secretary of the Air Force, Verne Orr. The memorandum stresses the importance of considering R&M throughout the acquisition process.

The memorandum recognizes the fact that current weapon systems may need modifications to improve R&M. As stated in the memorandum: "Many current systems will be with us into the next century. We need to make modifications which provide proven increases in reliability and address specific problems of maintainability "(21).

On 1 February 1985, the Reliability and Maintainability Action Plan (R&M 2000) was approved. This plan contains a multitude of actions to be accomplished in order to ensure R&M issues are considered throughout the Air Force. The plan states: "The action plan is aimed at ensuring R&M is considered across all of our weapon systems and treated equally with cost, schedule, and performance" (20:i).

Justification

With the high price tag of today's weapon systems and the limited budgets approved by Congress, the Air Force will have to reduce costs when acquiring new or modifying existing weapon systems while at the same time maintaining the war fighting capability necessary to meet the enemy threat. As General Mullins noted in a speech delivered at Martin Marietta, "our nation's strength is not in superior numbers, but in superior technology and weapon systems". Therefore, the Air Force must find the most efficient and effective way to get the most war fighting capability with the limited amount of money available (16:12).

One of the major cost drivers of owning a weapon system is maintenance. Maintenance, as a percentage of a system's life cycle cost (LCC), rose from 30 percent in 1960 to 70 percent in 1980 (25:44). Low reliability and poor maintainability of the weapon systems are two major maintenance cost drivers. As a result of poor reliability and maintainability, the weapon system is expensive to operate and unreliable in accomplishing its intended mission.

With the increases in R&M in electronics technology, the Air Force, through the Minimum Reliability of Electronic Systems policy letter #4, established a minimum reliability requirement of 2000 hours mean time between failure (MTBF) for a standard avionics LRU. (This requirement applies to a one Air Transport Rack (ATR) volume LRU in an airborne, uninhabited, fighter environment.) The goal is to have a 2000 hour mean time between maintenance action (MTBMA) for a one ATR size LRU by 1990. With a 2000 hour MTBMA, the Air Force can expect that an LRU would have a 90% chance of not failing in the first 30 days of combat (18:280). The examples that follow will illustrate how the aggressive goal of 2,000 hours (MTBF) is an achievable task with some surprising cost paybacks. "The oil-quantity-indicating system on the A-7 costs $11,000 and has a 200-hour mean time between maintenance (MTBM)" (29:68). In addition, more than 100 aborted missions per year are attributed to the oil-quantity-indicating system. It is also unrepairable. A modification to this item can now be purchased for $2,500-$3,000, and has an 18,000-hour MTBM. With the modification, cost avoidance over five years is estimated to be seven million dollars (29:68).

The offensive avionics system (OAS) on the B-52, which consisted of vacuum tube technology of the 1950's, has been replaced with solid-state technology of the late 1970's and early 1980's. Technology changes over that 20-year time frame resulted in far higher component reliability with single components replacing tens and even hundreds of 1950 vintage. The resulting increase in avionics reliability eliminated roughly 30% of B-52 avionics failures (26:7).

The new ring-laser-gyro inertial navigation unit (INU) on the F-15 replaces an INU that failed every 100 hours. The new INU has a mean time between failure of 2,000 hours and costs $39,000 less than the old INU. With the higher reliability, the savings in spares alone amounts to $94.2 million (29:68).

Other examples of successful R&M programs are the "ultra high frequency (UHF) modernization program, a tactical air navigation (TACAN) modernization program, and the upgrade for the APN-59B navigation weather radar used on cargo and tanker aircraft" (26:6). These three programs resulted in approximately $20 million being saved in depot maintenance man-hours each year.

With the success of these programs, R&M modification continued to expand to solve operational R&M problems. Program managers began to realize the benefits in both the cost savings of owernership and increases in combat capability that resulted in increasing the R&M of weapon systems.

There are problems to overcome in meeting R&M goals through modifications. There is little guidance in the Air Force for identifying field R&M problems. Also current data systems (MDC, Material Deficiency Reporting, and Technical Order Improvement Programs) may not be structured to identify R&M deficiencies. For example, T.O. 00-35D-54 USAF Materiel Deficiency Reporting and Investigating System says that a material deficiency report (MDR) is to be used as a hardware deficiency feedback mechanism (TO 00-35D-54:1-1). However, MDRs will not normally be submitted to report design, maintenance, and material deficiencies for work unit coded items on established weapon systems. Additionally, AFTO Forms 22, Technical Order Improvement Reports, should not be used to correct hardware problems. They are only used to report corrections needed to TOs (2:1).

Therefore, a new program manager needs to realize that no system will automatically identify a list of R&M problems on which to focus attention. In other words, there is no system to tell a program manager that he needs to work on a particular item to increase the R&M on his weapon system. Nevertheless, a program manager with a working knowledge of these systems can get an indication of where R&M problems may be occurring.

Investigative Questions

The purpose of this research was to identify methodologies specifically used to identify and correct R&M problems on already fielded USAF weapon systems. In order to complete this research, data was gathered by personal interviews with program managers currently working in ASD, AFLC, the Air Logistics Centers, and the operating commands on R&M programs. The following investigative questions were used in the interviews:

1. What is upper management's role in the identification of R&M problems?

2. Does your organization have a preplanned R&M improvement program? Explain.

3. What methods are used to identify R&M problems on fielded LRU's?

4. What data products are reviewed to identify R&M problems?

5. What role do maintenance personnel at the operational bases play in identifying R&M problems on fielded LRU's?

6. What role do contractors play in identifying R&M problems on fielded LRU's?

7. How do you justify the modification programs to improve R&M on fielded systems?

8. What are some R&M successes? Failures?

9. How long does it take a new program manager to become an important asset to the organization in identifying R&M problems on fielded weapon systems?

Scope

This thesis will deal only with hardware modifications to fielded Air Force weapon systems for R&M. There will be no discussion on improvements or updates to software. Also, this thesis is limited to how to identify and choose components or items for R&M improvement and will not cover the actual repair or improvement process once the items are chosen.

II. Literature Review

Introduction

There are many different sources of information that are helpful to program managers in solving R&M problems. Information can be obtained on R&M problems from maintenance data bases, operator complaints, personal suggestions from people in the field or repair depots, or programs and techniques for R&M improvement. Theoretically, R&M problems can be identified through Maintenance Data Collection (MDC) data received at the Air Logistics Centers, and this data is reviewed to identify R&M problems areas (2:2). However, new program managers may not know what to look for or more importantly what to ask for from the MDC data to identify R&M problems for his particular subsystem.

Technical reports and studies dealing with R&M abound. These reports, however, involve engineering considerations related to designing and predicting reliability of new systems or equipment. Areas covered in these studies include tradeoff analyses to determine optimum reliability, relationships between R&M, acquisition costs, life cycle costs, and mathematical functions to predict reliability (2:3). Very few studies have been conducted on the other end of the scale: dealing with improving R&M after the system is fielded.

This research focuses on the process of identifying unreliable fielded weapon systems or components of these systems, and the benefits of applying reliability and maintainability improvements to these weapon systems or components. Examples will be given in this research of problems, solutions, and benefits of reliability and maintainability in fielded weapon systems. The first step in improving the R&M of any weapon system is to identify the major drivers for poor R&M in that particular weapon system and justify an improvement that will increase the system's or component's R&M. This initial process is the hardest for a new program manager to get a handle on, and will be the focus of this chapter.

Method of Organization

The goals of this chapter are to document a review of the R&M literature and to draw conclusions from it. This chapter will give the reader information from the literature that will be useful in understanding reliability and maintainability and the benefits of improving the R&M of fielded weapon systems. R&M definitions will be covered first, along with examples of common reliability and maintainability problems. This chapter is organized around the following process of weapon systems improvement: gathering data, prioritizing items, justifying and selecting items for improvement, and the vehicles used to implement modifications to the chosen items. There will be a discussion on Failure Reporting and Corrective Action Systems (FRACAS) to give the reader an overall view of how to improve a weapon system. The Pareto Principle for indentifying and prioritizing top burners will be discussed. One section of this chapter will be dedicated to an example of how to use the MDC data system and the kinds of R&M information one can retrieve from it. An example using the D056 data base for the 1984-85 F-16 A/B fleet will be addressed. Consideration will be given to using maintenance, test and repair organizations to help identify R&M problems. There is a section discussing the process of justifying modifications to weapon systems, using Life Cycle Cost (LCC) and force enhancement models. There is also a discussion on Product Improvement Working Groups (PIWGs) and their use in selection items for modification. The Air Force Weapon System Master Plan (WSMP) process will be described as a vehicle for the implementation of improvements. This thesis will discuss how this process is used to identify current deficiencies in the force structure, and the engineering change process. A discussion of Air Force R&M initiatives will follow, including examples of successful R&M modification programs.

Definitions

According to AFR 800-18, reliability is "the probability that an item will perform its intended function for a specified interval under stated conditions."(6:2) According to DOD Directive 5000.40, maintainability is "the ability of an item to be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources."(7:2)

During the course of the chapter, references will be made to problem areas that some may consider maintenance or quality type problems. Examples of these problem areas may include reducing the servicing intervals needed for a item, or reducing the number of bad soldering joints, or loose nuts and bolts within an item. The author is considering all of these types of problem areas under the broad topic of R&M. In what follows, program managers will learn more specific problem types and areas considered under R&M.

R&M Problems

While R&M are often used together, they are different disciplines. When looking for R&M problems in fielded weapon systems, it is important to be able to distinguish between reliability problems and maintainability problems. Knowing the difference can be an aid to R&M decisionmakers.

Suppose that the goal of an R&M improvement program is to increase aircraft availability and that the apparent reason for the aircraft being unavailable is the failure of a particular component. Further suppose the problem is simply that the component failed (broke) frequently and had to be replaced. Identifying the part is easy. However, the aircraft is in maintenance a large portion of its time simply because the component failed frequently, not because of poor maintainability. The problem is clearly a component reliability problem. The fix is straightforward: make the component more reliable.

On the other hand, suppose the problem is with a subsystem that the pilots continually report as malfunctioning. Also suppose that typically the maintenance people are unable to duplicate the problem and hence are unable to fix it. The apparent failure may be real, but intermittent. It may have been a manifestation or reflection of a problem with a completely different subsystem. Or it may have been the result of a failed component, but one that is difficult to isolate. This problem is quite different from the one described earlier. Here the solution is much more complex. Improved test equipment, more highly skilled maintenance technicians, redesign of the entire subsystem, or any combination of these may be required. This problem is primarily one of maintainability (17:5).

Examples of R&M Problems

The following are some common R&M problems. By reviewing the following list of problems a program manager should be able to quickly determine the type, either reliability or maintainability, of problem he is working with.

1. Reliability:

Material: An inherent malfunction due to an unpredictable failure of a component or subassembly.
Quality: An error in workmanship, non-conformance to technical requirements, failure to provide or account for all parts in repair kits, improper adjustment or calibration (2:3).

2. Maintainability:

Inaccessability: Components are hard to get to when inspecting, servicing, or repairing.
Supportability: Maintenance requires special tools and/or test equipment which are not always available.
Technical Orders: Omissions, inaccuracies, failure to specify the best way to perform maintenance tasks,etc.
Excessive Maintenance: A component or system requires excessive servicing, calibration or repairing in order to maintain it in a serviceable condition.
Excessive Depot Support: Components are returned to depot for repair when the technical expertise to repair the item is available at the base level
Lack of Standardization: Components with similar function cannot be substituted for one another.
Malfunction Detection: Design does not allow for rapid and/or positive detection of component malfunctions.
Excessive Cannot Duplicate: Erroneous component failure indications causing maintenance actions on equipment.
Excessive Retest OK: Bench checks of components show no defect (2:3-4).

Measures of R&M

In the past, contracts have not adequately addressed the reliability and maintainability requirements of weapon systems. In part, this failure may have been due to lack of meaningful, quantitative methods to derive, state, and measure the desired characteristics (11:10). For example, if a program manager contracts for a 150-hour mean time between failure (MTBF), what is meant by failure? Does it count only hardware failures the way system reliability predictions do? Are software errors that result in system outages included? Or, is 150-hours the minimum MTBF expected by the user regardless of the cause of system failure? Whatever the definition, the specified MTBF should be stated to avoid any misunderstanding (8:25).

TAC found it more meaningful to express aircraft R&M requirements in terms like break rate, fix rate, and combat turn time to measure operational output. The break rate showed the reliability impact of the system in terms of required maintenance while the fix rate showed the maintainability impact in terms of the percent of aircraft returned to mission capable status in a given period of time. The use of these terms provided a positive way of tracking and measuring the R&M requirements in an operational environment with existing data collection systems (14:36).

Information Gathering

Air Force guidance in the area of weapon system improvement is given in documents like AFR 66-30, but these documents are not much help in telling the program manager exactly what tasks he should be doing to improve the R&M of his particular weapon system.

AFR 66-30 Product Improvement Policy (PIP) gives guidelines on improving the cost-effectiveness, readiness, and safety of products in the Air Force operational inventory. It states that program managers should use feedback information to identify and correct design deficiencies and to improve acquisition, maintenance, and operating policy. AFR 66-30 requires responsible Air Force activity personnel review and analyze systems, subsystems, and equipment in operation to determine components that contribute to high cost of ownership, to degraded readiness, to marginal or unsatisfactory performance, and to establish deficiency priorities. To help the program managers accomplish these tasks, AFR 66-30 calls out the following sources of information; Maintenance Data Collection system (MDC), Materiel Deficiency Reporting and Investigation System, data from engineering, maintenance, supply, and related programs, documented deficiencies that the operating and supporting commands identify during operational use, and the Air Force Acquisition Logistics Division lessons learned data bank (4:1-2). A few of these data sources will be discussed below.

The single source for worldwide MDC data is in the D056 system maintained at Headquarters Air Force Logistics Command (AFLC) at Wright-Patterson Air Force Base. Each operating base transmits copies of its MDC files to AFLC once each month. AFLC edits certain records, eliminates duplicate records, drops certain variables, adds a few variables for its own use, adds activity data such as sorties, and flying time, combines the files from each base into fewer, larger files, and uses this data to prepare various reports. An example of using the D056 system to gather data on possible R&M problem areas will be covered latter in this chapter.

"Materiel Deficiency Reporting system (TO 00-35D-54)", prescribes the procedures for reporting materiel deficiencies identified on AF weapon systems and equipment. Materiel deficiency reports (MDRs) provide the using activity with a capability to report qualitative data on their problems. Comments, analysis, and recommendations may be included in the "Details" section of the MDR. Deficiencies on weapon systems or equipment under test and evaluation, in operational transition or major modification are reported as service reports (SR) to the AFSC or AFLC program office managing the system or equipment. All other MDRs are either reported to the prime ALC/MM or to the ALC/QA organization (3:2).

Another data product is "Maintenance Information Logically Analyzed And Presented (MILAP)", developed within the Tactical Air Command (TAC) to provide base-level maintenance analysis with standard formats for display of aircraft and system reliability and capability. MILAP contains maintenance data collection (MDC) data, maintenance management information and control system (MMICS) status and utilization, daily flying schedule and deviations from flying schedules, and debriefing data (3:5).

Three of the fourteen data products produced by MILAP may be helpful in identifying R&M problems on fielded weapon systems. These products are the On- and Off-Equipment Man-hour Detail or Summary, the System or Component Malfunction Report, and the G033 which reports downtimes.

"Centralized Data System (CDS)" is an F-16 aircraft and avionics automatic test station maintenance data reporting and tracking system. This contractor supported system provides five MAJCOM's (AFSC, AFLC, TAC, PACAF, and USAFE) the capability to track maintenance, configuration, and operational data throughout all levels of maintenance within the F-16 program.

The CDS provides the detailed data required by the tactical commands, as well as the management summary data for the support commands. Through the use of direct "on-line" CRT terminals, pilot debriefing information is inputted directly into the system. Based on the debrief, maintenance work orders are generated, acted upon and closed out. The information is tracked by the serial number of the LRU, by job number, action taken code, work unit code (WUC), and how malfunction code. This information enables AFLC to make more accurate spares predictions. As the maintenance and pilot debriefing forms are generated on the CRT screen, less paperwork and keypunching by the units is required, and the information is gathered "real time."

A unique feature of CDS is that it provides maintenance and management personnel with near real-time aircraft status, avionics tracking and test station status/tracking information (33).

Contractor data products can also be used to identify R&M problems. These reports come from the prime or subcontractor product assurance or QA shops and contain much of the same information as in MDC data. These reports are commonly called failure summary reports. These reports are particularly useful in the early stages of system deployment because the contractor is much more knowledgeable with the weapon system at that time and can usually spot problems easier than Air Force maintainers. One advantage of failure summary reports is that they usually have more detailed information about what failed and the corrective action taken than the MDRs, SRs, or MDC products.

Weapon system testing provides a valuable opportunity to obtain R&M data as well as to identify problem areas. Lack of realistic testing in an operational environment is often cited as a cause for failure to correct R&M deficiencies before fielding a system. Maintainability tests in particular have been singled out as misleading due to an artificial environment (14:36).

Aircraft mechanics and repair technicians are a lifeline to enhanced maintainability. They are the link between flight line and depot repair organizations and the functions charged with R&M responsibility and efficient achievement of Air Force R&M goals. ASFC test teams are frequently the first of their kind to come in contact with a new weapon system (34:10). Aircraft mechanics and repair technicians can communicate R&M problems to the function charged with R&M responsibility by submitting suggestions to their supervisors, who in turn passes the information forward.

Some of the biggest problems field technicians have found are failure to use standard bolts, fasteners, and modular construction concepts. The mechanic's experience with these items, both prior to and during test and evaluation, is an important source for data and inputs to program managers and critical to fielding useful TOs (34:11).

Many R&M problems can be identified at the base level or in depot repair shops because the maintenance and repair technicians and shop chiefs know what reliability and maintainability problems they have. However, identifying the root causes of R&M problems at the base level or repair shops is not a simple process due to the many types of problems (2:4).

Identifying R&M problems is an important part of the aircraft maintenance quality program. The ultimate goal of the quality program is to achieve efficient maintenance production and equipment reliability. The base-level R&M monitor will need Deputy Commander for Maintenance (DCM) support to effectively investigate R&M problems. Quality Control/Quality Assurance (QC/QA) has the technical expertise to conduct thorough investigations into suspected R&M problem areas in order to identify underlying cause(s) of the problem as well as to suggest corrective actions. (2:4)

Improvement Processes

To accomplish the R&M 2000 goals, program managers need a process to follow. Gneral processes for weapon system improvement are outlined in MIL-HDBK-189 Reliability Growth Process and AFR 66-30 Product Improvement Policy (PIP). The reliability growth process consist of five steps that include:

1. Detection of failure source,
2. Feedback of identified problems,
3. Redesign effort based on identified problems,
4. Building of improved hardware or software, and
5. Verification of improvements due to the redesign (15:1).

In addition to MIL-HDBK-189, AFR 66-30 outlines the following steps to achieve reliability improvement:

1. Review the operation of equipment in the field or in OT&E for adequate reliability.
2. Analyze systems with marginal or unsatisfactory performance to identify the nature and cause of the deficiency.
3. Identify possible corrective actions.
4. Use the results of the improvement efforts to keep the deficiencies from recurring in new equipment (4:2).

Even with a working knowledge of the above systems or organizations, a program manager needs to follow some type of overall improvement process or methodology. The next sections will discuss a commonly used process called Failure Reporting and Corrective Action System (FRACAS) and a prioritizing system know as the Pareto Principle that can be used as part of a FRACAS.

Failure Reporting and Corrective Action System (FRACAS)

Task 104 in MIL-STD-785B, "Reliability Programs for Systems and Equipment Development and Production" specifies a closed-loop FRACAS. People in acquisition will agree that any system or equipment development, should have some sort of FRACAS system to be successful. "A FRACAS is a cost effective process which results in improved system reliability" (24:9).

Figure 1 below is an illustration of a FRACAS which starts with a reliability development test for a system or item and concludes with the incorporation of the corrective action taken to improve the system or item. (The FRACAS does not have to be tied to a development test because any failure from any source can be used.)

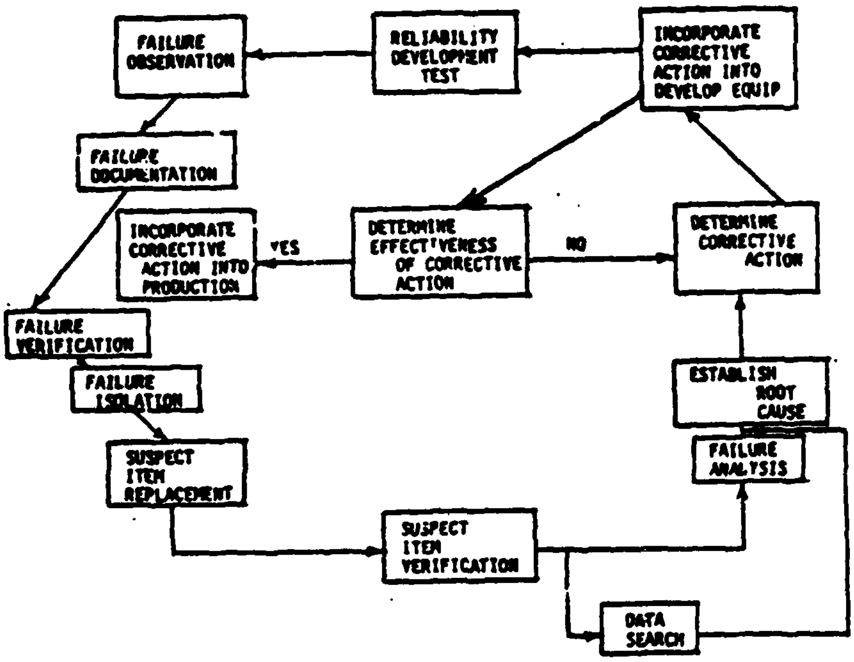

Figure 1. Failure Reporting And Corrective Action System (24:9)

In the process of identifying R&M problems in fielded weapon system, a program manager needs to be familiar with at least the FRACAS process through failure isolation. The FRACAS process starts with a reliability development test or gathering information on failures from any source. The purpose here is to observe a particular system for failures. The failures are documented which is part of a data collection system like MDC or suggestions from the users. A failure verification process follows for the identified failures. The next step and last one that this research is concerned with is the failure isolation to find the component causing the problem and the identification of that component for possible improvement (24:9).

The Pareto Principle

As part of a FRACAS, a well known process for identifying problem areas is the Pareto Principle. The use of the Pareto Principle to separate the "vital few" components or subsystems from the "trivial many" is one way to start the process of identifying the major R&M problems of any weapon system (13:9). The idea here is that a comparative few of the components of a system cause the majority of the R&M problems of that system. Clearly there will be no major improvement in R&M of a system unless there is a successful attack on the components causing the majority of the problems.

Based on the author's personal experience, the biggest problem in the Air Force for solving problems of any type is the lack of time, resources (manpower), and funding. In a program office or repair center, a program manager may have a long list of problem components that need to be worked, but how does he choose the components that will give him the most R&M improvement? This is the kind of situation where the Pareto Principle applies. The Pareto analysis applies to field failure types as well as to shop defect types. In the following automotive engine example (Table 1) there are 200 field failure types, but the top five (in order of frequency) account for a third of all the failures. The top 25 failures types (8% of the failure types) account for two thirds of the field failures. The aim is to find those components or failure types which show the highest concentration of R&M problem reduction in the fewest number of components or subsystems. In this simplified version of data, the term "failure rate" means number of failures per 100 engines during the warranty period.

Table 1 Pareto Analysis by Failure Type
Field Failures in Automotive Engines
(13:12)

Failure type	Failure rate	Cumulative failure rate
1	40	40
2	22	62
3	16	78
4	12	90
5	10	100
.	.	.
.	.	.
.	.	.
21	4	186
22	4	190
23	4	194
24	3	197
25	3	200
.	.	.
.	.	.
.	.	.
99	0.4	280
100	0.4	280
.	.	.
.	.	.
.	.	.
199	0.1	300
200	0.1	300

The question for the program manager is which items make up the "vital few"? The answer depends on factors such as the availability of time, resources, and funds available. Usually, the program manager will have many more items that need work than he has time, resources, and funds to work on them. In that case, the program manager would start at the top of the list and work as many of the items as he can. If that number is only one or two items, then the program manager should only concentrate his efforts on just those items. From the above example, a program manager concentrating his efforts on the top five items will help reduce one third of his failures.

Which items the program manager selects as projects depends on how well they compete against other nominations. The nominations for components or subsystems to be improved come from several sources. Some of nominations come from the management hierarchy i.e. managers, field operators, supervisors, professional specialists, and project teams. Another source is the work force, through informal ideas presented to supervisors, formal suggestions, and ideas from Quality Circles. Program managers can also find nominations from making the rounds to solicit nominations from various departments (13:12). The point here is that a process like Pareto analysis is just one source of determining candidates for possible R&M improvement, and a program manager knowledgeable in these areas can best improve the R&M on his weapon system.

Another question for the program manager, once he has identified an item to work, is how much improvement is enough? Usually the failure rates can not be reduced to zero, so a common goal is to reduce the failure rate by about fifty percent. A good common sense rule of thumb is to work the item as long as it is technically and economically feasible.

Maintenance Data Collection (MDC) System

One of the conclusions of a major IDA/OSD Reliability and Maintainability Study was that accurate and detailed engineering-quality information on system and component failures must be provided for identifying and solving equipment problems and focusing technology efforts (12:2-11).

The Maintenance Data Collection (MDC) system tracks maintenance action down to system, subsystem and item level. This data supports a variety of decision-making processes. Not only do design engineers need R&M data to evaluate their designs and measure reliability growth, but the Air Force uses this R&M data to confirm that contractual requirements have been satisfied. Also with this R&M data, the Air Force can address spares decisions, level-of-repair issues, and preventive maintenance by monitoring R&M to detect deterioration due to changes in operating environment, mission, management emphasis, or reporting discipline. Item modification may be required as a result of such deterioration, and hence R&M data support modification decisions by showing the items where most of the maintenance actions are being accomplished (20:E-16).

A RAND analysis of the MDC database came up with the following conclusions:

1. Contrary to widespread opinion, the MDC database is a valuable source for getting a first order fix on aircraft reliability and maintainability problems.
2. The two-step method of (A) distilling and reconfiguring the MDC database and (B) screening aircraft systems, subsystems, and components is a considerable help in identifying R&M improvement candidates.
3. The MDC data do not explain why there are R&M problems, and they are not adequate for making final decisions on improvement programs; yet, they are quite useful for raising questions and for focusing more in-depth queries.
4. The initial screening should typically be followed by site interviews and investigations to check the reasons for any high maintenance activity on a particular system before R&M improvement program is instituted on a particular system or component.
5. Variability in the data is important and should not be dismissed or overlooked (17:8).

DO56 Data System

The Air Force does not have a data collection and recording program specifically designed to accommodate all R&M management information needs. The most commonly used data processing system for R&M information is DO56. The total DO56 system receives about 500,000 records per week, can produce 49 different reports, and has a history of over 1,600 different articles of Air Force equipment (3:4). Currently, the Air Force publishes several DO56 analysis products that deal with R&M in one way or another.

DO56 is composed of five database systems: DO56A, DO56B, DO56C, DO56E, and DO56T. For purposes of identifying R&M problems on fielded weapon systems, DO56B, On-Equipment

Analysis, which performs analysis of on-equipment maintenance (work done at or near the item) for aircraft, engines, selected missiles, communications-electronics, support equipment, trainers, and special weapons is the best source of data to start with (3:5). In addition to the types of products available from HQ AFLC, AFALD Pamphlet 800-4 provides DO56 data that is summarized in yet a different manner. However, these routine products do not fully exploit the available information in terms useful to R&M managers (17:1).

All base-level maintenance actions reported in MDC are included in DO56. Each record (maintenance action) carries a record type code. The list of different record types (Table 2) suggests the kinds of maintenance activities that are recorded in DO56.

Table 2 DO56 Record Types (17:13)

Record Type Code	Record Description
A	On equipment aircraft
E	On equipment engine
G	On equipment nonairborne
H	Off equipment
P	Parts replaced during repair
R	Removal and installation of serialized components
S	Summarized aircraft support general
T	Removal and installation of aircraft engines

The source document for information input to the MDC, and hence to DO56, is the AFTO Form 349, which contains information reported regarding a maintenance task. Figure 2

MAINTENANCE DATA COLLECTION RECORD								OMB NO. 0704-0188
1. JOB CONTROL NO.	2. WORKCENTER	3. I.D. NO./SERIAL NO.	4. MDS	5. SRD	6. TIME	7 PRI	8. SORTIE NO.	9. LOCATION
10. ENG. TIME	11. ENGINE I.D.	12. INST ENG TIME	13. INST. ENG. I.D.	14.	15.	16.	17. TIME SPC REQ	18. JOB STD.
19. FSC	20. PART/LOT NUMBER	21. SER. NO./OPER. TIME	22. TAG NO.	23. INST. ITEM PART NO.	24. SERIAL NUMBER	25. OPER. TIME		

ACT. LINE	A TYPE MAINT	B COMP POS	C WORK UNIT CODE	D ACTION TAKEN	E WHEN DISC	F HOW MAL	G UNITS	H START HOUR	I STOP DAY	I STOP HOUR	J CREW SIZE	K CAT LAB	L CMD ACT ID	M SCH CODE	N AFSC/EMPLOYEE NUMBER
1															
2															
3															
4															
5															

26. DISCREPANCY
27. CORRECTIVE ACTION
28. RECORDS ACTION

AFTO FORM OCT 85 349 PREVIOUS EDITION WILL BE USED.

Figure 2. AFTO Form 349
(10:7)

is an AFTO Form 349.

Each line on the form is a single maintenance action. In principle, all maintenance actions undertaken to cure a particular fault should be recorded on a single AFTO Form 349. The AFTO Form 349 also shows the tail number of the aircraft worked on, the Work Unit Code (WUC) of the system or component, the work center of the maintenance people who did the work, how many people were involved, when the maintenance people started and when they finished, the circumstances under which the problem was discovered, the basic fault if one could be identified, the kinds of maintenance actions that were taken to cure the fault, and considerable additional information that is not of particular interest in identifying R&M problems (17:15).

In order to obtain R&M data for a system, one needs to extract type "A" (on equipment) records with Type Maintenance codes "B" (unscheduled maintenance) or "P" (periodic, phased, or major inspection) from the MDC system. Type maintenance codes are shown in Table 3.

Table 3 Aircraft Related Maintenance Type Codes (17:14)

Record Type Code	Maintenance Description
A	Service
B	Unscheduled maintenance
C	Basic postflight and through-flight inspection
D	Preflight inspection
E	Hourly postflight or minor inspection
H	Home station check
J	Calibration of operational equipment (non-PME)
P	Periodic, phased, or major inspection
Q	Forward support spares
R	Depot maintenance
S	Special inspection
T	Time Compliance Technical Order (TCTO)
Y	Aircraft transient maintenance

The WUC is used to identify the system, subsystem, LRU, or component/shop replaceable unit (SRU) on which work is required or performed. In the following example for the maintenance actions taken on the F-16 A/B fleet, the 2-digit WUC is used to identify the aircraft system, for example

WUC=74 is the fire control system. The 3-digit WUC is used to identify the aircraft subsystem, for example WUC=74A is the radar set. Finally, the 4-digit WUC is used to identify the LRU, for example WUC=74AO is the fire control radar set.

D056 Example

Using the D056 data base of MDC is one way a program manager can identify the high maintenance action items for a particular weapon system over a period of time to identify areas where possible R&M improvement can be made. The following section describes a method for extracting MDC data from the D056 database. Our goal of using the MDC system is to identify aircraft systems, subsystems, or components that are potential candidates for R&M improvement. The following example will demonstrate how the D056 data could be used to identify potential R&M problems on the F-16 A/B fleet.

In order to give an example of how R&M data can be extracted from MDC data, RAND used the D056 files for calendar years 1984 and 1985 for each of the eight bases that operated F-16 A or B aircraft. The purpose of obtaining this MDC data was to see if it is possible to identify R&M problem areas using this maintenance data for a major weapon system. Table 4 provides a summary of the number of equipment unscheduled maintenance jobs per thousand sorties performed at all eight bases during calendar year 1985. The data is broken out by major aircraft system (2-digit Work Unit Code) and by type of job.

Table 4
Job Counts per 1000 Sorties, by 2-Digit WUC
(17:30)

WUC	Aircraft System	Remove and Replace	No Defect Found	Minor Repair	Other	Total
11	Airframe	4.25	7.57	97.05	63.27	172.14
12	Crew Station	5.91	7.06	11.49	20.00	44.46
13	Landing Gear	32.76	10.73	48.93	11.81	104.23
14	Flight Controls	18.79	17.75	23.15	16.19	75.89
23	Turbofan Power Plant	19.06	15.80	15.53	15.45	65.84
24	Auxiliary Power/JFS	9.65	12.59	14.92	27.17	64.33
41	Environmental Control	6.96	8.54	4.82	7.79	28.11
42	Elect. Power Supply	15.63	14.38	8.05	18.33	56.39
44	Lighting	22.49	4.50	12.79	2.19	41.96
45	Hydraulic & Pneumatic	3.86	3.20	8.23	3.25	18.54
46	Fuel System	15.58	23.80	19.59	15.11	74.08
47	Oxygen	3.64	4.07	2.61	3.56	13.88
49	Misc. Utilities	0.27	0.73	0.84	0.33	2.17
51	Flight Instruments	10.99	5.30	4.41	2.85	23.55
55	Malfunction Analysis & Recording	0.52	0.51	1.46	4.94	7.43
62	VHF Communications	3.77	3.76	10.67	0.66	18.86
63	UHF Communications	6.85	6.18	4.80	2.22	20.04
64	Interphone	1.64	1.64	1.55	0.34	5.17
65	IFF	3.51	4.04	11.70	1.55	20.81
71	Radio Navigation	2.57	3.21	1.37	0.95	8.10
74	Fire Control	41.55	49.21	13.67	22.67	127.10
75	Weapons Delivery	21.23	47.02	10.01	19.67	97.94
76	Penetration Aids & ECM	14.43	18.71	7.61	6.53	47.28
91	Emergency Equipment	0.03	0.23	0.13	0.02	0.41
93	Drag Chute Equipment	0.00	0.01	0.02	0.01	0.04
96	Personnel & Miscellaneous Equipment	0.09	0.17	0.24	0.07	0.57
97	Explosive Devices Etc.	0.25	0.28	0.16	6.30	6.99
	Total	266.28	271.00	335.79	273.25	1146.32
	Percent	23.8	23.6	29.3	23.8	100.0

A glance at the totals in the right-hand column indicates that the single largest number of jobs was performed on the Airframe (WUC=11). The Fire Control system (WUC=74) is a close second, and Landing Gear (WUC=13) is third. The Weapon Delivery system (WUC=75) is next, etc.

One might suspect that the system receiving the most maintenance attention is the best candidate for reliability or maintainability improvement. Unfortunately, it is difficult to put the airframe in the same category as the fire control system. Note that this ranking occurs when one consider all types of jobs together.

The graph in Figure 3 does a much better job of showing the rankings by dividing the total into four groups: remove and replace, no defect found, minor repair and other. Note, the airframe jobs consist almost completely of "minor repair" and "other" jobs, and the fire control system jobs are predominantly "remove-and-replace" and "no-defect-found" jobs. Furthermore, "remove-and-replace" is probably the best indicator of reliability, and "no-defect-found" of maintainability problems (17:29).

By looking in depth at one of the aircraft systems, we will try to learn which items of that system are possible candidates for R&M improvement. The Fire Control System at the 3-digit work unit code level will be examined. Table 5 and figure 4 show the number of remove-and-replace and no-defect-found jobs for that system. Two subsystems, the Radar Set (WUC=74A) and the Inertial Navigation Set (WUC=74D) have the highest job counts.

Now lets take a closer look at the Fire Control System Radar Set. Table 6 and Figure 5 show the number of jobs per thousand sorties for the radar set and each of its components defined at the 4-digit work unit code level. Only

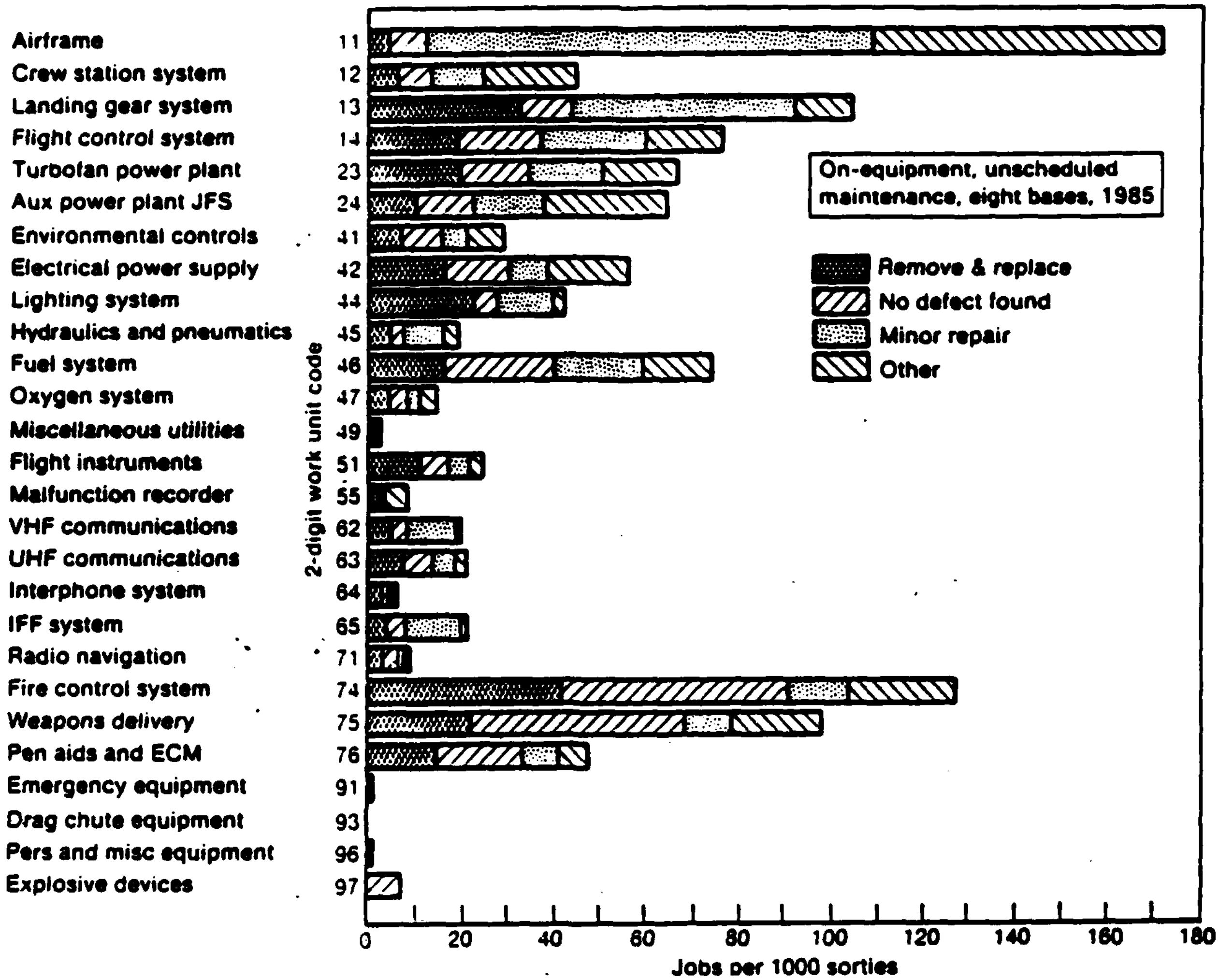

Figure 3 Graph of Job Counts, by 2-Digit WUC (17:31)

items having one or more jobs per 1000 sorties are included. The bad actor is system (WUC=74AO), the fire control radar set. Also, practically all of the jobs are no-defect-found jobs. No specific component was found to be at fault. The Low Power RF Unit (WUC=74AB) seems to dominate the remove-and-replace category of jobs.

Table 5 Job Counts per 1000 Sorties, by 3-Digit WUC (17:35)

WUC3	Subsystem	Removė and Replace	No Defect Found	Total
74A	Radar Set	15.37	19.25	34.62
74B	Head-up Display Set	4.42	3.96	8.37
74C	Computer	2.19	3.12	5.31
74D	Inertial Navigation Set	12.84	12.31	25.15
74E	Radar & E-O Display Set	4.20	3.50	7.70
74F	Target Identification Laser Set	0.00	0.01	0.01
74G	Airborne Video System	2.52	6.73	9.25
740	Fire Control System	0.00	0.33	0.33

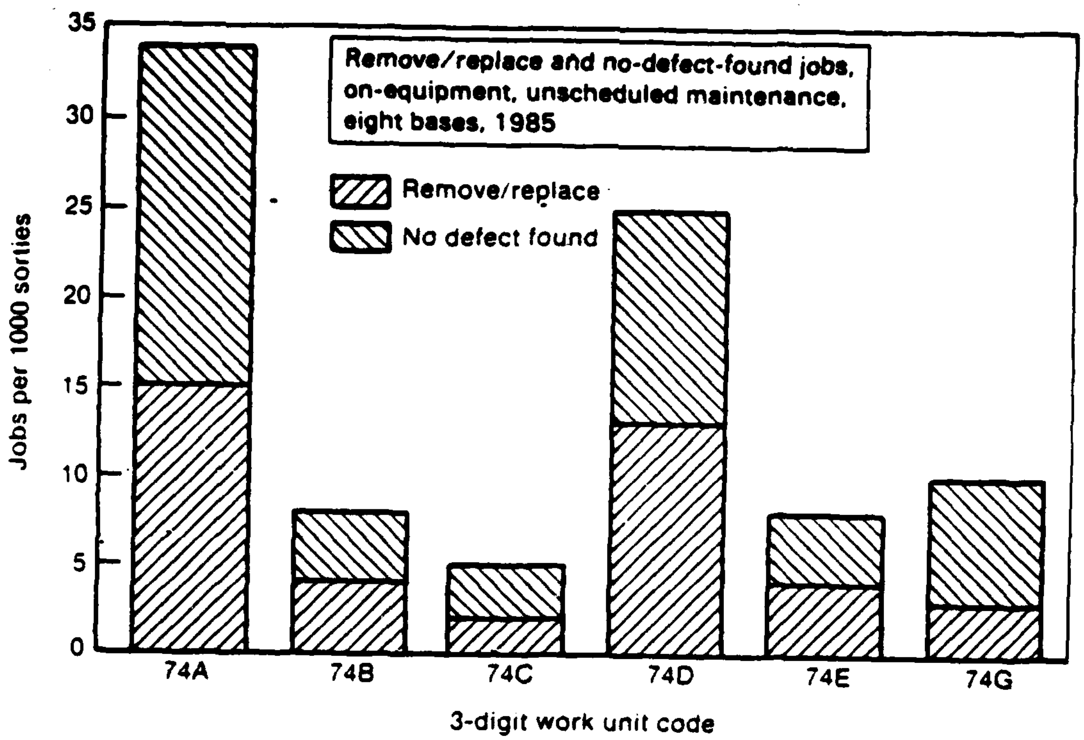

Figure 4 Graph of Job Counts, by 3-Digit WUC (17:36)

How much better off would things be if the problems identified so far were fixed? Given the data in Fig. 5, the Mean Sorties Between Jobs (MSBJ) for the entire radar system is approximately 29. Now suppose that one starts with WUC 74AO (Fire Control Radar Set), and reduces the no-defect-found jobs to 7.5 jobs per 1000 sorties (same MSBJ as for WUC 74AB, The Low Power RF Unit). It can then be calculated that the overall MSBJ has increased to about 41. Continuing in this way and reducing the incidence of failure (jobs per 1000 sorties) for 74AO and for 74AB to three per 1000 sorties (the same MSBJ as WUC 74AA), calculations reveal that the overall MSBJ has gone up to about 65. Thus, the MSBJ can be more than doubled by significantly reducing the number of no-defect-found jobs for the Fire Control Radar Set and improving the reliability of the Low Power RF Unit.

This is just the initial findings from a review of the D056 data. Granted, the two systems identified may be our high R&M drivers, but as mentioned before, there are other things the program manager should do or consider. The D056 data does not tell why these two components are having so many maintenance actions performed on them, but it does raise the question. The next step for the program manager may be a site visit to further investigate the questions raised by these two components.

Table 6 Job Counts per 1000 Sorties, by 4-Digit WUC (17:37)

WUC	Subsystem	Remove and Replace	No Defect Found	Total
Fire Control System Radar Set				
74A0	Fire Control Radar Set	0	17	17
74AB	Low Power RF Unit	6	1	7
74AA	Radar Antenna	2	0	2
74AC	Radar Transmitter	2	0	2
74AD	Digital Signal Processor	2	0	2
74AF	Radar Computer	2	0	2
	Total	14	18	32
Fire Control System Inertial Navigation Set				
74DA	Inertial Navigation Unit	8	2	10
74D0	Inertial Navigation Set	0	9	9
74DD	Fire Control System/Navigation Panel	3	1	4
74DB	INU Storage Battery	2	0	2
	Total	13	12	25

NOTE: Subsystems or components with less than one job per 1000 sorties are not shown.

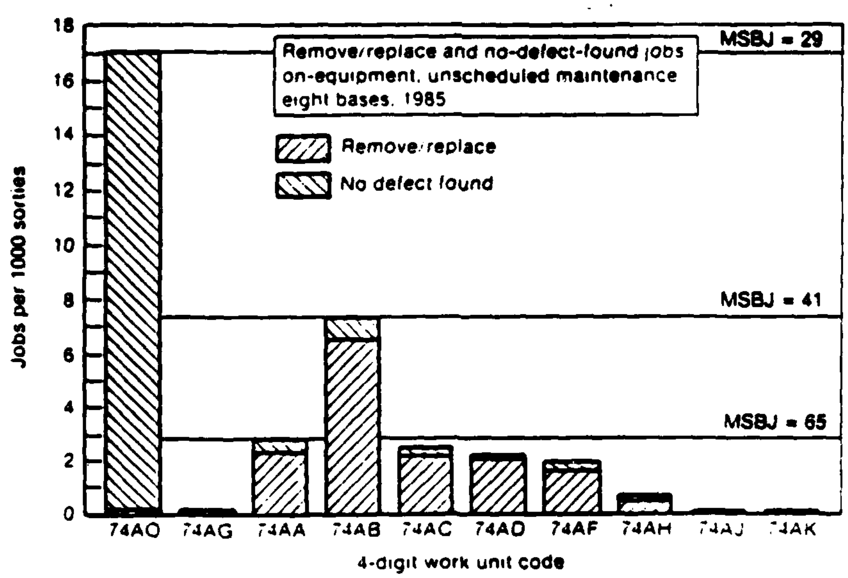

Figure 5 Graph of Job Counts, by 4-Digit WUC (17:36)

Air Force R&M Modification Initiatives

The following examples of Air Force initiatives to meet the R&M 2000 guidelines will give the program managers involved in R&M improvement efforts an idea of what different organizations are doing. These initiatives or programs incorporate many different sources of information to identify possible areas for R&M improvement. Initiatives or programs that will be discussed here are as follows: F-15 Multistage Improvement Program (MSIP), Special Management Organization for R&M (SMO-R&M), Product Improvement Working Group (PIWG), Air Force Blue Two Visit (BTV) Program, Technology Repair Center Failure Rate Reduction (TRC-FRR) Analysis, R&M Centers, and Pacer Impact, a Single Point of Contact (SPOCO) at each center, increasing R&M weighting factors within the modification prioritization process, Rivet Improve Program and AFLC Requirements Management Review.

AFR 800-2, Attachment 6, "Preplanned Product Improvement Procedures" proposes a phased approach for the acquisition of new system or the modification of existing systems. It allows for "provisions, interfaces, and accessibility" to be integrated into the initial system or modification design for latter incorporation. The objectives of this regulation are:

Reduce cost and schedule risk with new technological advances;
Upgrade weapon system capabilities to meet changes in mission or threat;
Exploit projected opportunities to enhance weapon system operational capability, readiness, or support,

or to reduce life cycle costs;
Extend the useful life of a weapon systems and;
Reduce logistics and support problems (5:1).

The F-15 SPO initiated a new improvement concept, known as the Multistage Improvement Program (MSIP), and allotted $1.8 billion worth of the F-15 modification funds to this program. The MSIP, which follows the guidelines of AFR 800-2, Attachment 6, "is a preplanned, logically grouped, and integrated set of phased improvements to incorporate new capabilities and technologies after production and deployment" (29:66). MSIP reverses the traditional thinking of managers who have tended to treat modifications as a "fix after failure" solution. Now, during the design and full-scale-development phases of acquisition, space provisions and interface components are designed into the production aircraft for modifications that may not even be available for years (29:66).

TAC established a Special Management Organization for R&M (SMO-R&M) under the Deputy Chief of Staff for Requirements. With the advent of R&M 2000, a product improvement manager has been established at each local unit. This person is now the central point of contact for all the ideas that are involved with improving the design and support of existing systems. The SMO-R&M at the local level has impressed the young troops that their ideas and suggestions for R&M improvement will receive greater emphasis (1:297)

The Air Force Logistics Command (AFLC) Product Improvement Working Group (PIWG) for weapon systems is another initiative for the improvement of R&M. The working group consists of weapon system managers from AFLC and the using commands along with component item managers from the depot. The purpose of a PIWG is to identify components with design deficiencies, low reliability, and/or poor maintainability. Once a problem is identified, possible solutions are presented along with a funding profile. The PIWG may potentially be the best vehicle for improving R&M in fielded aircraft systems. The operating commands are working hard with AFLC to improve the methodology used in identifying deficiencies for PIWG discussion to make it more responsive to the using command's field experience. Additionally, PIWG identified components are being brought to industry's attention for possible R&M improvement (1:298).

An important part of improving R&M in weapon systems is making the designer fully aware of the operational and maintenance environment. This is achieved through active support of the Air Force Blue Two Visit (BTV) Program. Named for the blue suit, two-stripe airmen on the flight line, this program exposes industry design engineers and Air Force acquisition personnel to real-world operating environments experienced by maintenance technicians. During a typical BTV, designers visit several operating locations to experience, in person, the weapon system supportability concerns they only read about in Air Force maintenance data collection and company equipment failure reports. The visits usually are made at the beginning of demonstration/ validation and full-scale development phases of programs (27:292).

After deployment of weapon systems, assessment of weapon system capability becomes an on-going process which is accomplished by the System Program Manager (SPM) and the Logistics Operations Center. Weapon system program reviews are being modified to reflect Air Force R&M goals.

Reliability and maintainability (R&M) within the depot maintenance environment are primarily a function of high quality repair and highly productive processes. Within the AFLC depots, several programs will lead to improved weapon system R&M through modifications. Three of these programs are Technology Repair Center Failure Rate Reduction (TRC-FRR) Analysis, R&M Centers, and Pacer Impact.

TRC-FRR is a process of completely analyzing all aspects of a low reliability and/or poorly maintainable item. The investigation includes all of the repair processes, equipment, data, training, spare parts, and technology insertion opportunities that could lead to more reliable or more maintainable items. Deficiencies, or outdated maintenance processes, that are contributing to the R&M problems are identified. This program targets maintenance R&M efforts on items that can be improved the most through improved maintenance rather than through redesign.

R&M Centers is a program that solicits knowledge and experience of the mechanics and technicians who are actually performing depot maintenance. They see problems daily and they are the ones who must try to do a good job with what they are given. The R&M Center helps the workers articulate their ideas to identify and correct R&M problems, and then hepls the workers to incorporate any proposed solution that can best solve the problem (i.e., through value engineering or suggestions). These R&M Centers are located in the production areas for high visibility and easy access (28:301). Problems requiring solutions and solutions that have been incorporated as fixes to previous problems are publicized. This work force involvement in R&M is one of the keys to the future success of the program within depot maintenance.

Pacer Impact, the AFLC Depot Maintenance productivity improvement program, uses development groups composed of representatives from each depot to address specific productivity improvement areas. The Methods and Process Development Group, for example, evaluates the repair or manufacture process and seeks to improve productivity and reliability while reducing costs. Group members also evaluate high cost throw-away items and identify repair processes that improve maintainability and reduce cost. Since Pacer Impact has a computerized reporting system, it has become the umbrella program within depot maintenance for reporting and tracking all maintenance R&M initiatives (28:302).

The Materiel Management Directorates manage all AFLC modifications to existing weapon systems, develop purchase request for spare parts, and determine depot repair requirements. A few of the many R&M actions undertaken in the Materiel Management (MM) Directorates include development of a Single Point of Contact (SPOCO) at each center, increasing R&M weighting factors within the modification prioritization process, and including R&M assessments as part of the Requirements Management Review (RMR) procedures.

A SPOCO has been identified at each Air Logistics Center for all users needing an interface point. The SPOCO receives, distributes and tracks all incoming deficiency reports, R&M hardware initiatives outside MM, performs an initial analysis, and ensures that the right offices are identified to analyze fixes. Additionally, new computer based management tools are being developed for R&M processing and analysis.

The ALC Command modification ranking process is also being altered to give R&M criteria more weight in relation to the factors that are used to rack-and-stack modifications. When the alteration is completed, R&M factors will have approximately three times as much weight as previously computed.

The product improvement process is also undergoing enhancement. The Rivet Improve program has been initiated to correct systemic and institutional factors that prevent rapid implementation of weapon system improvements. Rivet Improve involves streamlining the product improvement process by reducing the number of noncritical materiel deficiency reports (MDRs), establishing Product Improvement Working Groups (PIWGs) to handle non-critical MDRs, and limiting MDR submission to only critical defects.

One way to improve the R&M of existing weapon system is through the procurement of "preferred spares" for existing items on weapon systems. A perferred spare is an new item that meets the requirements of the existing item, and in some cases is cheaper, easier to maintian, and has a higher reliability than the item it replaces. The preferred spare can result from new manufacturing techniques, or other economic conditions that result in cheaper better items.

The AFLC Requirements Management Review is used to assess the validity of purchase request that are processed for parts reprocurement. The review procedures are being modified to ensure that R&M consideration are included in the decision process that justifies development of new purchase requests for parts. The objective is to ensure that higher reliability preferred spares are procured whenever available (28:302).

Justification

Depending on where a person works in the Air Force, he can follow any of the above mentioned initiatives or programs to identify possible candidates for R&M improvement. In order for a program manager to start a modification program on the items he has identified, he must show some justification to upper management to use limited resources and funds for his proposed modifications. Two methods of justifying modifications are the use of life cycle cost (LCC) and effectiveness models.

Life Cycle Cost (LCC) Model

Based on a cost comparison between a proposed modification to the current operating and support costs of a system, a judgment can be made whether the proposed modification will reduce cost. LCC includes research and development costs, acquisition costs, operating and support costs, and any salvage/disposal costs of any modification. Most organization in the Air Force use LCC models to determine the ranking of proposed items for modification.

One of the problems with using LCC to justify a modification project is large up front acquisition costs for new systems. For example, a program manager may use LCC to compare two candidate items. Item A is the existing item on the weapon system, and item B is a proposed improved item. The LCC model may show that item B is much more cost effective over the life time of the weapon system, but the program manager may not have the up front funding to buy item B. Unless Item B can be purchased as a preferred spare, item B may not incorporated into the weapon system. The point the author is trying to make is that a program manager can not justify a modification project solely on the basis of LCC analysis. Keep in mind that reducing cost is number five on the list of R&M 2000 goals, not number one.

Effectiveness Model

The concept behind an effectiveness model is to identify critical subsystems or components that contribute the most to the accomplishment of the weapon system's mission. For example, a model for a bomber would measure which subsystem or component imposes the greatest limitation on damage expectancy (DE) for the bomber's mission. Damage expectancy is the probability of mission success made up of mission elements such as prelaunch survivability, weapon system reliability, probability to penetrate, and probability of damage.

Figure 6 will illustrate the differences in increasing warfighting capability that would result from improving the R&M of subsystems or components identified by using effectiveness and LCC models. The key point is that improving the R&M on a subsystem or component based solely on cost reduction will not increase the warfighting capability of that weapon system to a great extent. However, increasing the R&M of subsystems or components identified with effectiveness models will give a greater increase in warfighting capability.

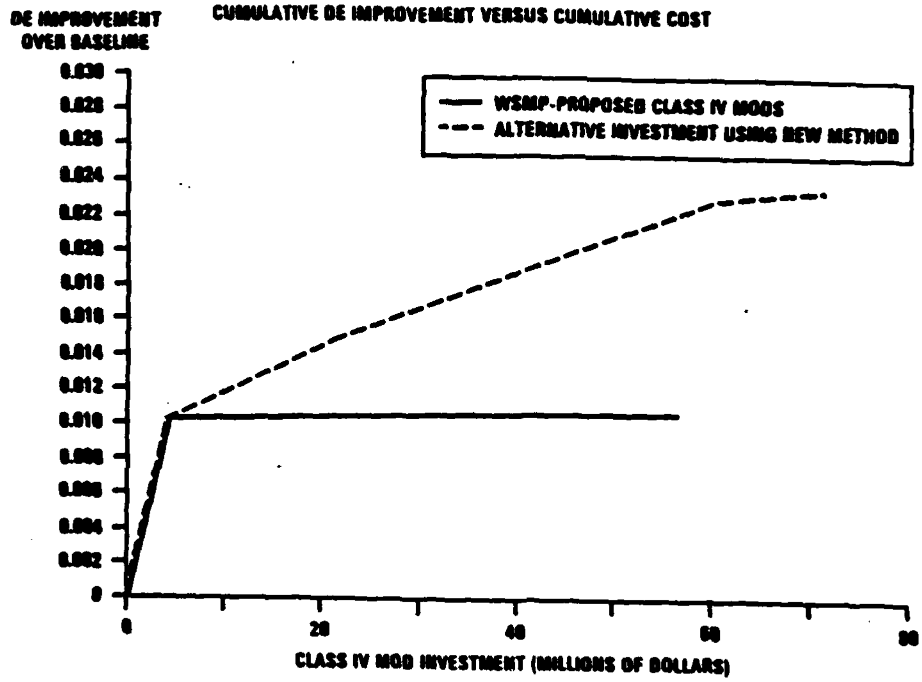

Figure 6 Warfighting Capability vs LCC (31:15)

SAC is currently working on a methodology to be used in quantifying each R&M goal. It is using a model called the Methodology for Analyzing Reliability and Maintainability Goals and Investments (MARGI) to measure increases in combat capability of proposed modifications.

MARGI, initiated in June 1986, is only operational for assessing the effect of R&M improvements on combat capability for the B-52 Single Integrated Operational Plan (SIOP) mission. MARGI assesses the effect and relative worth of proposed modifications to the damage effectiveness of the B-52 bomber. It was used in setting command goals included in the B-52 Weapon System Master Plan. This model lends a sense of credibility to modification proposals by tying R&M improvements to increased combat capability. Eventually, effectiveness models will assess all five R&M 2000 goal areas to further enhance the Air Force, proposes and ranks modifications. (30:IV-5)

By comparing the top ten items identified in the WSMP for the B-52 using MODAS to the top ten items identified by MARGI, a program manager can see that depending on the criteria used, either most maintenance actions taken or damage expectancy, the ranking of items differs. Table 7 below will illustrate a comparison between the items listed using the MODAS and the MARGI model.

Using MODAS, the top candidates are selected and prioritized based on the number of maintenance actions preformed on an item during a specified time interval. MARGI on the other hand selects and prioritizes items by the increases an improvement to that item will have on damage expectancy. Based on the use of different criteria for selection and prioritization, different items will be at the top of the respective list.

Program managers should keep in mind the five R&M 2000 goals when making up a prioritized list of candidate items for improvement. The number one goal is to increase combat capability, and force effectiveness models like MARGI are designed to select items that will increase combat

Table 7 Top Burners (31)

	MODAS	MARGI
1.	FIRE CNTL SYS	REINST TERRAIN CMPTR
2.	ALT-28/ALQ-155	EVS FLIR
3.	RADAR SET GROUP	EVS PRESENTATION
4.	AN/ALQ-117	RADAR SET GROUP
5.	INERTIAL NAV SYSTEM	OAS CMPTR
6.	RECV SYSTEM ALR-20	AIR REFUELING
7.	FUEL TANK SYSTEM	ALT-28/ALQ-155
8.	TURB & TURB EXH SECT	INS
9.	EVS PRESENTATION	AHRS
10.	EVS FLIR	DOPPLER

capability for that particular weapon system. On the other hand, MODAS will give the items that have the most maintenance actions taken, and these items may or may not improve combat capability.

Weapon System Master Plan

R&M projects originate from many different sources. The most common of these sources are accident investigations, materiel-deficiency reports, inspections, new technology applications, and even the Air Force Suggestion program. External to the materiel system are modifications generated by mission area analysis or enemy threat changes which may demand a whole new capability (29:66).

The vehicle for documentation of candidate modification projects is the Weapon System Master Plan (WSMP) process, with Logistics Command, Systems Command, and the operating commands all in the loop. Conceived by AFLC and now a recognized Air Force program, a WSMP is a longterm contract between the combat commands and Logistics Command. It starts with a view of what Air Force planners expect each weapon system to do for the next ten years. System program managers specify the current capabilities of the system. In between these two points is a delta - a void that must be filled. Defining the technology, performance, and R&M options to fill the void will set modification requirements in the years ahead. The WSMP further allows the commands involved to express their requirements credibly, with a single voice (29:65).

Successful R&M Modification Programs

The following are two examples of R&M programs that resulted in weapon system improvement. The first program, PRAM, is actually a basket system program office working on many different fielded weapon systems. The second, Falcon C, was an F-16 initiative to resolve R&M type problems on the F-16 A/B fleet and incorporate the fixes in the F-16 C/Daircraft before they were deployed to field units. Both of these programs used the methods of gathering data, prioritizing and selecting items for R&M improvement as discribed earlier.

PRAM

The Productivity Reliability Availability Maintainability (PRAM) program office has the mission to improve combat readiness and reduce current and potential operations and support cost, through increasing the reliability and maintainability of Air Force systems, subsystems, and equipment or productivity of in place maintenance/repair processes.

An example of a successful PRAM project is the Engine Bleed Air Check and Shutoff Value For F-111 Environmental Control System This PRAM project will replace the current valve with a higher reliability design successfully proven on the A-10 aircraft. This design is half the cost of the old valve, has a service life of over 2000 hours (compared to 950 hours for the old valve), and is much easier to repair (19).

The process of developing, approving, funding, and completing a PRAM project is a fairly simple, streamlined process. The key points are the idea, the Project Plan, the PRAM Board review, and the Final Report.

The PRAM process begins with an idea to reduce Air Force cost or enhance system readiness. The idea can originate with anyone. This idea is outlined in a brief PRAM Project Plan which outlines the actions necessary to accomplish the desired results. The PRAM program manager with help of the person generating the idea usually writes the PRAM project plan. PRAM program managers are located either at the home PRAM office or at one of the interface satellite PRAM locations mentioned earlier. Before PRAM can sponsor a project, however, a responsible organization must be committed to implement the successful prototype effort. This commitment is essential, since no savings will occur without implementation.

The plan is submitted to the USAF PRAM Program Office for funding approval. The Board meets twice a month, or as necessary, to provide a prompt response. The candidate projects are reviewed by the board and, if approved, funding is provided to accomplish the improvement project.

At the completion of the PRAM effort a final report documents the results of the project. Successful prototypes are then implemented as widely as possible, resulting in significant cost savings for the Air Force.

F-16 Falcon-C Program

The primary purpose of Falcon C was to identify design problems early in the F-16 C/D program so that design changes can be made in production before the fleet size made retrofit extremely costly and manpower intensive. The program was initiated to correct problems in the F-16 A/B fleet and incorporate these fixes into the F-16 C/D production.

Falcon C followed the general improvement process of gathering data, prioritizing and selecting items to work. It also relied on coordinated efforts from all players, and had backing by upper management which resulted in overall improvements in R&M for the F-16 fleet.

Very few organizations have the resources to resolve all issues simultaneously and the F-16 SPO was no different. Therefore, they had to prioritize not only the problems to be resolved, but also the fixes to these problems. They selected the problems and fixes that had the greatest return on investment. The maintenance data base used in the Falcon C program was CDS and the items were prioritized much the same way as described using the D056 system.

Falcon C was fully backed by highly motivated management. Dedicated management is probably the one most important factor for the success of a Falcon C type program, especially high-level management. The overall leader must recognize that some problems will not get worked immediately, or at least not with the same priority, and he must allow the subordinates to concentrate on the priority issues.

Falcon C used a PIWG approach for the F-16. Coordinated efforts between all the players paid big dividends. The manufacturer, or prime contractor, usually knows more about problems and solutions for his hardware than anyone else. The user is important in identifying the problems that affect him most. He must be intimately involved in the whole process. Who better than the person with his hands on the equipment to tell about the problems? Supporting agencies were also involved to complete the task force. ALCs (Item Managers), depot overhaul facilities, ASD labs, and other supporting agencies must be on-board (32).

Table 8 will illustrate the results achieved from the Falcon C R&M improvement program. These LRUs were some of the items worked during the Falcon C program and from the results obtained one can see the benefits of this PIWG.

Table 8 Results of Falcon C

(32:86-(MCS)#72/9C-705)

LRU	MTBF JUL 85	MTBF AUG 86
DEEU	240 HRS	425 HRS
ACIU	140 HRS	352 HRS
PDG	225 HRS	785 HRS
EFCC	170 HRS	255 HRS

DEEU - Data Entry Electronic Unit, ACIU - Advanced Central Interface Unit, PDG - Programable Display Generator, EFCC - Enhanced Fire Control Computer

Summary

This chapter has given the reader an overview of the literature dealing with reliability and maintainability. The reader now has a well defined idea of what makes up a weapon system R&M improvement program. The reader has an overview of the kinds of information and the sources for obtaining this information to prioritize and select candidate items for R&M improvement. He also has seen examples of R&M initiatives and programs in use in the Air Force, and the benefits that can be achieved with R&M improvements.

III. Methodology

Introduction

This chapter will discuss the approach used to study current procedures used in identifying R&M problems in fielded weapon systems. The quest for improved reliability and maintainability seemingly starts with the design and build functions of our weapon systems. There are, however, many latter opportunities, after the system is fielded, for us to make significant improvements. The identification of purely R&M problems is a complex task. In order to study the processes and methodologies of identifying R&M problems in fielded weapon systems used in the Air Force today, experienced personnel involved in R&M were interviewed.

Population

In order to obtain a broad perspective on the current methodologies of identifying R&M problems, personnel from HQ Air Force Systems Command (AFSC), Aeronautical Systems Division (ASD) System Program Offices (SPOs), HQ Air Force Logistics Command, the Air Logistics Centers, HQ MAC, HQ SAC, and HQ TAC were interviewed. Personnel involved in Air Force R&M programs at the major weapon system and subsystem level comprised the research population.

Personnel interviewed were lower ranking program managers and R&M engineers experienced in R&M programs. They were located at the working (branch) level within the organizations. Interviewing the lower ranks within the organization determined the kinds of R&M jobs a newly assigned program manager may have, and evaluated the effects of R&M programs, like R&M 2000, are having on the working levels within the organization. By interviewing these people, this research determined if the goals of the Air Force R&M 2000 program are being meet.

Research Instrument

A questionnaire was developed which served as the basis for questions asked during interviews. The nature of the research necessitated development of open-ended questions. Validation of the questionnaire took place as a pre-test of seven program managers and engineers working in the PRAM office and the F-16 SPO. The following questions were asked during the validation phase:

1. What methods are used to identify potential R&M problems on fielded LRU's (reactive/proactive)? What sources of reference are used?
2. How do you justify the modifications?
3. What data products are reviewed to identify R&M problems?
4. What are the essential elements of a successful R&M program? Is there a list of criteria and standards (boiler plate) from which to choose from?
5. What are incentives and/or impediments to R&M?
6. What are your R&M initiatives (planned or in process)?
7. What are some R&M successes and failures?
8. Do you use the five Air Force goals presented in R&M 2000?
9. What role do maintenance personnel play in identifying R&M problems on fielded LRU's?
10. What role do contractors play in identifying R&M problems on fielded LRU's?
11. What is management's role in the identification of R&M problems?
12. What are your recommendations for identifying R&M problems on fielded LRU's?

After the pretest of the survey instrument, the questionnaire was revised as follows:

1. What is upper management's role in the identification of R&M problems?
2. Does your organization have a preplanned R&M improvement program?
3. What methods are used to identify potential R&M problems on fielded LRU's?
4. What data products are reviewed to identify R&M problems?
5. What role do maintenance personnel at the operational bases play in identifying R&M problems on fielded LRU's?
6. What role do contractors play in identifying R&M problems on fielded LRU's?
7. How do you justify the modification programs to improve R&M on fielded systems?
8. What are some R&M successes? Failures?
9. How long does it take a new program manager to become an important asset to the organization in identifying R&M problems on fielded weapon systems?

The interview questions were generated to followed the first two steps in the guidelines of (MIL-HNBK-189) Reliability Growth Process and AFR 66-30 Product Improvement Policy (PIP). Again, the first two steps called out in the reliability growth process are:

1. Detection of failure source,

2. Feedback of identified problems,

and the first two steps in AFR 66-30 are:

1. Review the operation of equipment in the field or in OT&E for adequate reliability.

2. Analyze systems with marginal or unsatisfactory performance to identify the nature and cause of the deficiency.

The basis for establishing each of the above listed questions was as follows:

Question 1 determined how upper management influences the identification of R&M problems. This question was asked to determine if the worker bees thought that upper management was supporting the R&M push in the Air Force. It also collected any examples of how upper management could influence an R&M program.

Question 2 was developed to determine if organizations have an ongoing effort to identify R&M problems on an scheduled bases. The idea was to determine if the organization as a whole was trying to work on R&M problems or whether working on these problems is left up to each program manager.

Question 3 was developed to determine if program managers at the worker level were using a process for identifying R&M problems and what that process was. This question could also determine if program managers were initiating their own programs or processes to identify R&M problems, or whether upper management or operations commanders were identifying which items should get the most attention. The latter being a more reactive approach to solving R&M problems.

Question 4 was developed to determine if program managers use data bases like the Material Deficiency Reporting (MDR) system, DO56 systems, and Service Reports on a routine basis to identify failure trends on their particular LRUs, or do they wait until a problem emerges before taking action to review these data bases. This question was also use to identify any in-house R&M data bases.

Question 5 determined if program managers are aware of the experience and help maintenance personnel can contribute to an R&M improvement program. This is especially true at test centers like Eglin, Edwards, and Kirtland AFBs. This question also holds true for the people working in the repair centers at each of the ALC's.

Question 6 evaluated the use of contractors in the role of identifying R&M problems on fielded LRUs.

Question 7 was developed to determine how a program manager justifies to upper management that the R&M problems he has identified deserve corrective action. Since most corrective actions or modifications require some sort of funding or expenditure of limited resources, upper management makes the final decisions on which R&M projects to implement. This question gained insight into the kinds of things that are important to upper management in putting an item at the top of an prioritized list for possible improvement.

Question 8 was asked to find what kind of experience in R&M programs the program managers have? This question is also in line with objective IV, action E, of the R&M 2000 action plan, which is to "establish a system to identify generic R&M needs, innovations, and technological successes and transfer this information across all applicable weapon systems to guarantee maximum utility and payback are attained from the investments and actions." (memo1:H-27) This question seeks to identify success stories. Program managers at the working level can give insight to what works best for them. This question is also inline with objective V of the R&M 2000 action plan to "identify and promote successful R&M programs from the technology base and from development, production, and fielded system to serve as models and standards of excellence across the Air Force." (memo1:H-30)

Question 9 was asked to determine the time frame and experience needed to become and effective R&M program manager at the worker level. One of the hopes of this research is to being newly assigned program managers up to speed on the R&M world as so as possible. This question was asked to determine if the new program managers were ready to start an R&M project, and if not how could the experience time be shortened.

Data Analysis

Analysis of the interview results did not involve quantitative procedures, but rather a qualitative review and compilation of interview responses. An analysis consisting of an integration of responses to the questions allows the overall views of those interviewed to be readily available. The analysis of the responses was not separated by organization, but remained a collection of responses from all those interviewed. The goal is to let the new program manager know of the many different methodologies used to identify R&M problems on fielded weapon systems, so that he can solve his particular R&M problems.

IV. Findings

Overview

This chapter presents the results of 31 interviews with people in the Air Force working on R&M problems in fielded weapon systems (see appendix). The results are a combination of findings from many different offices and organizations. Therefore, any one particular office may not be using the exact methods mentioned. However, it is useful for anyone working on R&M problems on fielded weapon systems to be aware of what the different organizations in the Air Force are doing in relation to identifying R&M problems. By following the example of the suggested process outlined in Chapter V, a program manager can identify where to start to solve his particular R&M problem.

This chapter starts out with a discussion about the role of upper management in identifying R&M projects. It then moves to a discussion of the process of gathering data, prioritizing a list of candidate items to work, and then the justification and selection of which items to work to best improve the R&M of the system. The F-16 Falcon C R&M improvement program will be used as an example throughout this chapter. As mention before, the Falcon C program was initiated to improve components with low R&M on the F-16 A/B fleet before the deployment of these components on the F-16 C/D fleet. It was initiated in the early stages of deployment for the F-16 C/D aircraft, but the process could be followed for other aircraft that have been in the field for some time.

<u>Findings</u>

The first step to be discussed is the role of upper Air Force management in the initiation of efforts to identify R&M problems on fielded weapon systems. Upper management as used here refers to the SPO director or ALC commander level. The responses of the interviewees were as follows. Senior Air Force managers are committed to R&M improvements. They are voicing the benefits of R&M improvements and providing for R&M education. They foster a positive R&M environment by placing a lot of emphasis on R&M, and by sponsoring R&M committees like the R&M executive steering group that meets quarterly. Air Force generals have initiated programs like the R&M and technology insertion program at the ALCs, so the item managers can order new improved parts (preferred spares). They believe in R&M, and understand the R&M improvement process. They support initiatives like AFCOLRs blue two visits, SAC's R&M videotape (SAC video 115) to increase R&M awareness, and provide overall R&M direction by keeping R&M issues on the top of their agendas. They are the decision makers, and when a R&M problem is identified and funds are requested to investigate possible solutions, they are providing the necessary funds and resources.

Upper management supported the F-16 Falcon C program. The SPO director supported this program by chairing the

Falcon PIWG meetings. A General Dynamics senior vice president for engineering co-chaired the PIWGs. As a result of this high level attention, Falcon C initiatives received top priority for resources. This level of upper management support from both the Air Force and the Contractor, fostered a cooperative environment to find and implement solutions to R&M problems. The primary goal was to identify problems and implement solutions without placing blame, and this type of cooperative work is much easier with high level support.

The next two questions were asked to identify any organizational improvement programs or initiatives and the methods used to identify R&M problems. The responses to these questions indicated that there were a multitude of programs or initiatives, all with the goal of identifying R&M problems, that the people either knew about or were personally involved with. The idea behind these initiatives and programs was to follow some process to identify candidate items for improvement. Depending on where the program manager works (ASD, AFLC, or the operating commands) determined the areas in which to look to identify problems. For example, a program manager working in a SPO environment may start with maintenance repair data, or talk to the quality assurance people at the manufacturer to identify potential R&M problems. However, a program manager working at an ALC may want to investigate the repair processes of an LRU for possible improvement, or the program manager working in an operating command may want to find which LRUs are causing the most MICAPs for his aircraft.

The overall response was that the people interviewed actually used some method or plan to identify R&M problems on their particular weapon systems. Most respondees identified the "bad actors" down to the LRU level for their particular system or subsystem. The identification of "bad actors" came from reviewing information sources like maintenance data bases, field support visits, contractor service reports, lessons learned data bases, critical item lists, and even complaints from field commanders.

Some of the programs or initiatives mentioned to identify items with R&M problems were the F-16 Falcon C, PRAM, F-15 MSIP, preplanned product improvement, critical item list programs, WRSK reviews, purchase request reviews for R&M considerations, weapon system program reviews, requirements management reviews, the weapon system management information system/substance assessment model, command weapon system update, PIWGs, R&M focal point meetings, quarterly director boards, and the critical item resolution board. Preplanned Class 4B modification efforts to improve system or subsystem R&M through the use of preferred spares for items at the ALCs were also mentioned.

Once the "bad actors" have been identified, a prioritized list of LRUs to be investigated was generated. This list usually contained the top 5, 10 or 20 LRUs for a particular weapon system or subsystem. The LRUs that appeared at the top of the "bad actors" list were the items with the highest maintenance actions taken, type 1 failures, maintenance manhours per flight-hour, aborts, or other things considered to be wartime limiters or having an impact on flight safety. Once the respondees came up with a potential candidate for R&M improvement, they then approached their bosses for direction.

An example of how the improvement process worked is the Falcon C PIWG. A Falcon C review was chaired by the SPO director and a senior manager from the prime contractor and had representatives from all concerned parties (System Command, Logistic Command, TAC, and subcontractors) for the F-16 Information was presented on the top 20 LRUs causing the F-16 fleet the most problems. The identification of these top burners will be discussed in more detail in the sections on maintenance data bases, and the roles of maintenance, repair, and contractor personnel. Once a prioritized list of the top LRUs was agreed to, each LRU was assigned to a program manager to find what the problem was and propose a solution. Possible causes to the problems and solutions were to be presented at the next Falcon C review. If a solution to a particular problem was agreed to by the members of the Falcon C PIWG, the next step was to implement the corrective action either into production, or into the already fielded F-16 fleet, or both. At each Falcon C review, new LRUs would be added to the top 20 list as solutions were implemented to LRUs identified in previous reviews.

The next question determined the data products used in identifying R&M problems. By data products, the author is referring to any computer source of information that can be used to help identify or justify possible R&M improvements.

The most common answers to this question were to use data processing systems like D056, D041, CDS, G033, and the weapon system management information system (WSMIS). Where the program manager is working and the type of information he is looking for, would determine which data system he would use.

The three most commonly used data collection systems were the AFR 66-1 Maintenance Data Collection (MDC) system for maintenance data, AFR 67-1 for supply data, and AFR 65-110 for aircraft status, utilization, and flight hour data. For each of these data collection systems there is a data processing system. For example the processing systems for MDC are D056, MODAS, CDS, and the AFALCP 800-4 which comes from D056 data. The processing system for AFR 67-1 supply data is D041, and the processing system for AFR 65-110 data is G033 and WSMIS.

The most common use of these data sources by the respondees was to identify the items with the most maintenance actions taken for a particular time period, or the most supply actions, or the LRUs that contributed to low aircraft utilization rates. Other responses were to review various reports from quality circles, PIWGs or maintenance personnel. Since contractors usually keep records on quality and repair for the items they manufacture, they put out various repair analysis reports that could be useful in determining the causes of R&M problems.

Of the more than thirty people interviewed, only two of them actually did the data processing (number crunching) using the data processing systems. The others did not, but they were very aware of these data sources and, more importantly, knew where to get the information needed on their items. They would normally request the data on their item at the 4-digit work unit code level.

CDS was the most commonly used data base to identify R&M problems during Falcon C. Since many people participated in the Falcon C PIWGs, many other data sources were also used. The CDS data was provided by logistics analysts prior to each meeting, sorted at the 4-digit work unit code level.

The next question was asked to determine the role of maintenance people at the operating locations and repair people at the depots in identifying R&M problems. Some reports have suggested that maintenance people know what problems they are having, usually know how to fix the problems, but nobody asks them. The following responses were given to this question. They (maintenance or repair personnel) can bring problems to the attention of the R&M focal points at the R&M centers at the ALCs, or to the unit

R&M representative. They can identify the bad actors through MDRs, QDRs, or SRs, and can put meaningful information in the write-ups of these reports. They can keep accurate repair records and make sure this information gets into the MDC system. They can participate in PIWGs, the AF Suggestion Program, quality circles, Blue Two Visits, and field support visits. They can use the PRAM hotline at the ALCs and HQ SAC, TAC, and MAC. They can also submit ideas to AFCOLR's logistic needs program.

From the information obtained in the interviews, the respondees believe that maintenance and repair personnel are the best sources of information on the current problems of Air Force weapon systems. These people have a keen insight into exactly what is going on with a particular item. Even though in some cases they may not know what is causing the problem or how to quantify the problem, they can definitely tell a program manager were the problems are occurring.

Falcon C always invited Deputy Commanders for maintenance (DCMs) and maintenance troops from the operating bases, and repair personnel from the depots to confirm a problem LRU identified with the data systems. These people were also very valuable in identifying problems that would not show up in data reports.

A good example is a problem with the nose wheel steering on the F-16. The problem did not occur often enough to be a bad actor in data systems like MDC, but when it did occur, the aircraft would run off the runway. This problem was brought up by TAC DCMs and a solution was found. Problems like this with high management level attention tend to get favorable backing by PIWG members. Other safety of flight problems can be identified in much the same way.

The next question determined the role of contractors in identifying R&M problems. The contractor are the ones who actually build our weapon systems, so who better to help solve problems? The following responses were obtained. Contractors are very helpful during maintenance support, putting data into the MDC system, and in coming up with fixes to problems. They can usually perform data analysis and can spot R&M problems easier during the early stages of deployment than Air Force maintainers. This is due to the contractor having more experience with the system than the Air Force troops at those stages. They may also have better manufacturing and repair shops for a particular LRU than the Air Force which makes it easier to identify solutions to R&M problems. The reason being a supplier may only produce and repair one LRU while an ALC which repairs hundreds. This supplier will usually have a quality control shop, and maintain accurate repair records for that one LRU.

In addition, contractors can be used in field support teams. They can also submit unsoliciated proposals to help solve R&M problems identified in AFCOLR's logistics needs program. They are very helpful in face-to-face coordination on R&M issues. They run contractor fairs and trade shows to let the government know the existence and benefits of new processes and technologies. They attend Air Force R&M reviews either at the field location or at the contractor plant to help resolve R&M issues. They can perform tear-down analysis of the repair of a particular unit to identify exactly why the unit failed. Most of the people in ASD used contractors to help identify R&M problems early in production and deployment, but contractors were not used as problem finders by many AFLC people. The reason AFLC did not use contractor support very often was that the system was generally out of the contractors hands by the time AFLC took the system over and became the major repair center.

Because Falcon C took place during the early stages of weapon system production and deployment, contractor support was widely use to improve R&M on the F-16. For example, one of the LRUs identified as a problem was the converter regulator. This LRU had a very high can-not-duplicate (CND) rate. As a result, the supply of spares was used up and the F-16 MICAP rate was high due to this LRU. Through the use of tear-down analyses, site visits to the subcontractor's plant and the help of the subcontractor's quality control personnel, the converter regulator program manager was able to determine the reasons why the CND rate was so high. With full support from the subcontractor, he proposed solutions to the problem to the Falcon C PIWG, and approval was given to proceed with implementation of the corrections to the problem. As a result, the CND rate for the converter regulator dropped from about 60% to 20% in less than one year.

Another question was asked to determine methods of justifying R&M improvement projects. The responses to this question indicated that the people interviewed did not always use the same rationale to convince their bosses to fund R&M projects.

The people interviewed said the best way to get approval for an R&M project is to show upper management how the R&M improvement could increase combat capability, reduce required logistic support, increase utilization or mission capable rates or reduce cost. Basically the respondees said that if you could show that the modification to the LRU would increase the five goals of the R&M 2000 plan, that was justification enough in most cases.

The most common justification, by far, was the use of life cycle cost models to show a reduction in acquisition, repair, maintenance or support cost for the system or subsystem. For Class-4 modification, the criteria for approval was usually a return-on-investment of five years or less which is basically the use of a LCC model. Since decreasing cost is the fifth AF R&M 2000 goal, some offices used force enhancement models like MARGI. These models justified the projects by showing how war-fighting capability would be improved when the project was incorporated.

Another method of justification came from agreements made during PIWG meetings. The criteria used in these meetings could be anything from the TAC general saying "fix it", to LCC models, force enhancement models, or flight safety issues.

Approval of a PRAM project was also mentioned because PRAM supplied funds for the R&M improvement so the organization did not have to worry about money. PRAM is not an approval method for R&M projects, but is actually a funding source. Therefore, a manager is likely to let his people participate in a PRAM project that could improve the R&M of his system as long as there is no additional cost to his organization.

Program managers need to be aware of what criteria or methods works best for their particular office in order to be successful in getting his R&M projects approved.

Falcon C managers gained approval for their projects during the PIWGs. Since many different players had already agreed that there was a problem and the proposed fix should work, PIWG approval meant SPO approval.

The next question asked to determine if the people interviewed were aware of the benefits of R&M improvements. The following are just some of the examples mentioned that will illustrate that the people interviewed were very aware of the benefits of R&M improvements. The F-16 fuel tanks had an assess panel added and blind fasteners were changed to solid rivets which saved $15 million in maintenance costs; replacing the fuel quantity indicator for the F-4 with a digital indicator which was a form-fit-function (preferred spare) replacement increased the MTBF many times over; the F-111 digital signal transfer unit was upgraded with a VHSIC insertion program which increased the MTBF from about 40 to 5000 hours and reduced the acquisition cost from $24 to $2 thousand; the C-5B has about 100 R&M improvements compared with the C-5A which decreased the maintenance man-hours per flying hour from about 80 to 35; the repair time for the tail light on the C-5 was reduced from about four hours to 15 minutes which saved $80,000 per year; the steerable TV on the B-52 has a much higher MTBF resulting from replacing the vacuum tube technology components with preferred spares that are solid state.

The last interview question was asked to get an idea of the time it takes a new program manager to become effective in the methodologies of identifying R&M problems in fielded weapon systems. No consensus was reached since the answers to this question ranged from six months to six years. The point to keep in mind here is that new program managers may start to be effective in their particular jobs within their organization during the first six months. However, weapon systems cross many different organizational boundaries between the Acquiring Command, the Using Commands, and Supporting Command. It may take several years before a new program manager can interface well with these different organizations. This is evident by the make up of a PIWG for any weapon system.

The PIWG may be made up of representatives from the SPO, the users, the labs, the contractors, the maintainers, and the item and systems managers. The new program manager needs to be aware of these organization and how they can help him in identifying potential R&M problems in fielded weapon systems. The next chapter will provide a recommended procedure for identifying field R&M problems for modifications.

V. Recommended Procedure of Identifying R&M Problems

Introduction

The purpose of this research was to identify the methods used to identify potential R&M problems on fielded weapon systems with the goal of helping new program managers understand the improvement process. The author hopes that the information that follows will help decrease the time it usually takes for a new program manager to become useful in solving R&M problems for his system or subsystem.

The process that follows starts with determining a performance criteria used by organization for its particular weapon system, and then examines data sources used to identify "bad actors" based on the criteria. The next step is to use some method to prioritize a list of candidate items for improvement, followed by the selection of items to work. The final step is to get management approval to start the improvement process.

Criteria

The initial step in identifying R&M problems on fielded weapon systems is to develop a list of candidate items to consider. In order to accomplish this task, performance criteria must be established based on the impact of the item to the weapon system. To be effective, the criteria must be meaningful and measurable. For example, do not measure how long the paint lasts if the item performs just as well without paint. The question for the new program manager is what to use as criteria for his particular system, and how to measure this criteria?

Different organizations have different focui and criteria for the weapon systems they manage. The criteria could be cost, MTBF, breakrate, damage expectancy, or aircraft utilization rates. The program manager should know what criteria his particular organization is using, and become familiar with the methods of measuring this criteria.

The concerns of other agencies may influence the selection of criteria. A concern of the user of the weapon system is to increase the war fighting capability, while a concern of the supporters is how to reduce repair and other support costs. The measures of increases in war fighting capability or reduction in O&S cost may take many forms, for example *increasing mission capable* (MC), MICAP, MTBF, MTBD rates, or solving the problems on the front line. The users may complain that they are having problems meeting their mission requirements due to an R&M type problem. The Air Logistics Centers want to reduce cost of repair, and save money by spares reduction, airlift reduction, and reduced manpower requirements. Depending on what organization the program manager works, he should be familiar with these criteria because they can be used to identify R&M projects and show the benefits of R&M improvements.

Once the criteria is developed, the program manager should measure each item's performance against the criteria, and generate a list of possible items for improvement with the lowest performance rate at the top of the list. One example, would be to use MTBF as the criteria and list the items with the lowest MTBF at the top of the list down to the 4-digit work unit code level. However, keep in mind that the LRUs with the lowest MTBF may not indicate the high drivers with regards to the five R&M 2000 goals as pointed out when we looked at the MARGI effectiveness model example in chapter two. The next section will discuss methods of gathering information on "bad actors".

Data Gathering

The new program manager will need to become aware of the types of data bases in his organization and the information he can get from these data bases. The program manager could used maintenance repair data, collected from Air Force or contractor data bases like DO56, and from interfacing with personnel working in maintenance or repair facilities. The following sections will illustrate examples of the types of data available to program managers.

Maintenance Repair Data

Program managers and engineers may or may not personally used the MDC system, but they should be aware of what information they could get from MDC and the people to ask for this information in their organizations. Item Managers/System Managers at the ALC's or the logistics analysis folks in the SPOs can check failure data in the MDC system and provide a list of the "bad actors" much the same way as described in chapter two. This initial look at the maintenance data will usually give a program manager a place to start his candidate component list for R&M improvement.

New program managers should realize that contractors are being paid to collect and analyze maintenance data on many weapon systems. In most cases, the contractor is using the same MDC data that the Air Force analyst are using, but they may also have repair data from subvendors that Air Force analysts may not have access to. Contractors build our weapon systems and can often identify R&M problem areas easier than Air Force personnel. They usually keep repair records on the equipment and are able to help solve problems. The bottom line is that a program manager should either learn to use maintenance, supply, or operational data bases, or should develop a contact list of Air Force and contractor personnel who can supply him with this information.

Maintenance and Repair Personnel

Another very important source of information a program manager should use is personal contacts with the users and maintainers of his weapon system. The new program manager should become very familiar with all the key players of his weapon system, and know how to set up R&M reviews or meetings with these people and ask the right questions to identify problem areas.

The maintenance people at the operating base or repair person at the depot know what problems they are having with a particular LRU or component. Therefore, the program manager should realize the great benefits that can come from maintenance people identifying problems and possible solutions to the people who can implement a fix. This identification process can be the complete write-up in MDRs submitted to SPOs or the ALCs, or the submission of a suggestion on the AF Form 1000. Since these people are active participants in the R&M centers and Quality Circles at the ALCs and operating bases, the program manager should find contacts at the ALCs and bases. These people are also the key players in submitting ideas to AFCOLR for their Log Needs Program, therefore a program manager also needs to review the log needs program for possible improvements to his particular LRU.

Maintenance and repair people can be valuable, active members of PIWG tiger teams for the weapon systems maintained or repaired at their organization, so the program manager should make sure these people are invited to participate in these meetings. A frustration to the maintenance or repair people is simply that no one asked them for their advice. This unfortunate situation can be changed by program managers participating in activities like "blue-two" visits.

The key point to consider is that maintenance or repair personnel at the operational bases or the depots are valuable sources of information on R&M problems on fielded weapon systems, and the program manager should use them to help solve his R&M problems. The program manager should know who the key players are at each operating base and depot or contractor repair facility. However, the program manager needs to realize that even though these people can often point out the problems they are having with a particular component, they may have difficulty quantifying and expressing theses problems in measurable terms. The program manager should be familiar with reports (MDRs, and SRs) put out by these people and review them on his particular LRU to help identify R&M problems.

Using the above methods for identifying potential R&M problems, the program manager can now generate a projects candidate list. The initial ranking order can only be used as an indicator and should not be the only means for selecting problems to be worked. Safety impacts may dictate that the program manager work items lower on the list. Most important is to select only as many problems as you can effectively work. If that number is one, then so be it. It is better to resolve one problem than to just review ten.

Prioritization and Selection

The next step in identifying R&M problems for the new program manager is knowing how to prioritize a list of candidate items for R&M improvement. The program manager will usually generate a list of candidate projects from maintenance data sources and personal contacts that is larger than he has the capability to work. He will now have to come up with a prioritized list of candidate projects to review.

A program manager may cut off the list of top burners at two points, such as the top ten and top twenty by using the Pareto Principle discussed earlier, In this way, he can establish his bad problems and his worse problems. Other considerations such as LRUs affecting saftey of flight must also be considered.

Once the LRU is established as a potential candidate for an R&M improvement, the next step is to check with the contractor and/or repair organization to see if there is an on-going project to improve the R&M for that LRU or component. If not, the program manager should initiate a investigation to identify possible solutions to the problem.

Taking the candidate list of components identified using the above methods, the next step for the program manager is to set up an engineering review or PIWG to verify that the components are indeed causing problems. The PIWG should consist of as many people as it might take to identify the root causes of the problem. During the review, program managers should look at other data sources like MDRs, SRs and QDRs submitted on the item in question.

One important step before the PIWG is to visit the field units (flight line or repair shop) that are having the problems, and talk to the people actually working on or repairing that particular component. The primary reason for the field visits is to try and quantify the R&M problem under investigation, and experience first hand the problems the maintenance and repair people are having.

The program manager for a particular weapon system should invite everyone that has an interest in that weapon system to the PIWG meeting. These meetings should be held at the SPO or the prime contractor's facilities if the weapon system is in the early stages of production and deployment, or at the prime ALC if the weapon system had been turned over to AFLC. The participants at these meetings should review data from the maintenance, supply, and operational data bases to identify potential R&M problems.

The top LRUs identified by these data bases should be reviewed to determine if in fact these LRUs are causing undo problems and whether or not some improvement effort was warranted. Other problems not identified by the data bases should be brought up for discussion. The end result of a PIWG should be a well planned coordinated effort to investigate the causes of low R&M for the identified LRUs. The causes and/or solutions to the problems should be briefed at the next PIWG. Once a particular R&M problem is solved, the next LRU on the top burner list should be addressed.

There are many programs or initiatives currently is use in the Air Force to select R&M problems to work, and depending in which organization a program manager is working will determine the method used to identify and select R&M problems on his particular system. Many of these programs and initiatives are discussed in chapters two and four.

The program manager should learn the methods used by his office, but needs to watch for opportunites to use other methods discussed.

When an item is finally selected, it must remain in work until completed or no longer cost-effective to work. Again, you can't work all problems simultaneously. Priorities should only be changed for extreme emergencies and fully coordinated with all players. For example, flight safety issues may surface that will take priority.

<u>Justification</u>

A problem faced by the program manager is the justification of modification programs after an LRU or component has been identified as a candidate for R&M improvement. By justification, the author means how the program manager can obtain permission or authorization to use funds and resources to work on a particular item. Without the justification for the use of money and resources, no R&M improvements will be made.

The most common method the program manager can use to justify an R&M improvement is the use of Life Cycle Cost (LCC) analysis or LCC avoidance. The program manager should be familiar with LCC models, and how to use the outputs of these models to convince their bosses to spend the necessary funds for the improvement.

Another justification tool is the use of force effectiveness models discussed earlier. These models are more in tune with the five R&M 2000 goals. A program manager can use these models to show his boss how an improvement on a LRU will increase the effectiveness of the weapon system. The result of this and other justification technques will be the approval of the necessary funds and resources the program manager needs to accomplish the R&M improvements.

Approval and Implementation

The final step in the improvement process is to obtain upper management approval, usually in the form of funds and resources, to either continue the investigation into the problem or implement possible solutions to the problem. Solutions can be implemented through the engineering change process, or if modification funds are not currently available, through R&M improvement programs like PRAM. If nothing can be done imediately the items can be incoorporated into the weapon system master plan for later consideration.

The whole idea of bringing an item to the attention of upper management is to get approval from upper management to implement solutions to the problem. Without approval and the release of funds and resources to the program manager, no R&M improvements can be made. Senior managers are committed to the push for higher R&M by providing the funds and resources necessary for R&M improvement projects. There is a lot of emphasis placed on R&M by upper management as shown by General Officer Steering Groups for R&M improvement projects. A program manager should be able to show to upper management that he has identified an R&M problem and needs the necessary funds to implement a solution. With proper justification upper management will usually permit him to continue with the improvement project.

To accomplish these tasks, the program manager should become familiar with his organization's change process. The change process is how any organization initiates changes to its weapon system. For example in SPOs, the change process is usually through a Business Management Board (BMD) or through a PIWG. The ALCs and using commands also use PIWGs and other reviews like the critical item review board to initiate changes to their weapon systems. By being familiar with these processes or reviews, the program manager will know the proper forum to bring up R&M improvement efforts.

VI. Conclusions/Recommendations

Conclusions

Through analysis of current guidance and interviews with personnel involved in R&M within Aeronautical Systems Division (ASD), the Air Force Logistics Command (AFLC), and the operating commands, this thesis provides insight into the current methodologies of identifying R&M problems in fielded weapon systems. As stated in chapter one, there is no system specifically designed to identify R&M problems on fielded weapon systems. It is the author's opinion that there never will be a single system for identifying R&M problems because of the many different organization within the Air Force with varying missions to accomplish. This research did however identify how program managers working in any organization can use a process starting with gathering data, to get an initial list of items which maybe R&M problems. The second step in the process is to generate a prioritized list of candidate items to investigate. The third step is to select and justify the particular items for R&M improvements. The final step in the process is to obtain upper management support and approval for the R&M improvement to the selected items.

During the research, the author learned that many of the people working to identify R&M problems did not use the maintenance data collection system directly. These people relied on logistics or data analysis professionals to provide them with MDC information on their particular weapon system. Therefore, an understanding of how to operate the data system is not as important as knowing the information contained in them.

Another observation was that many of the interviewees were too busy with normal day-to-day work to identify additional areas for improvement. They were to busy responding to what their bosses gave them to do and did not have the time to investigate other problems. However, one concern might be that the problems these people were working on are <u>not</u> the problems that are causing the most troubles to the weapon system.

It is the hope of the author that the information contained in the thesis will be of help in steering new program managers in the right direction in the business of R&M improvement. There is no substitute for experience, and this thesis will not make a fully competent R&M program manager overnight. This thesis will however get a new program manager thinking in the correct direction to identify R&M problems on his particular weapon system or subsystem. Also, it is the hope of the author that this thesis will reduce some of the anxiety of new program managers coming into the complex world of program management and R&M improvements.

Recommendations

From the results of this research, it is apparent that most people in the R&M improvement business are basing their selection of items for improvement on cost reduction.

In looking back at the five R&M 2000 goals, we see reducing cost is at the bottom of the list. Only two organization, HQ SAC and HQ MAC, used force effectiveness models to help identify areas for improvement. HQ SAC actually has an operational model and HQ MAC is currently working on a similar model. The author recommends that ASD and AFLC investigate the use of force effectiveness models to identify LRUs which contribute the most to the five R&M 2000 goals. The Air Force needs a way of setting up selection criteria for LRUs that contribute the most to the R&M 2000 goals. Effectiveness models may be the answer.

Future areas of research in the R&M improvement process should look at the PIWG process and the methods that these groups use to select items for improvement. Some organizations like HQ TAC are reviewing the methods and terminologies used during PIWGs to come up with a common language that is easily understood by everyone involved.

Program managers working to improve R&M on our weapon systems should go to school in the areas of R&M. These people should be allowed to visit contractor plants and operational field units to get a first-hand look at the way things are done in the Air Force. They should also visit and become very familiar with the Air Force Logistics Centers and how they operate. The R&M business cuts across many different organizational boundaries, and program managers familiar with how these organizations work together has a better chance of implementing his improvements.

Appendix: Interviews

1. Adams, Rick, E-3, F-15 Assitant Control Officer. Telephone interview. AFLC/LOC/TLWB, Wright-Patterson AFB OH, 25 April 1988.

2. Adkins, Howard, Logistic Management Specialist. Personal interview. PRAM Program Office, Wright -Patterson AFB OH, 4 March 1988.

3. Anderson, Capt. Jeffrey, R&M Engineer. Personal interview. AFALC/ER, Wright-Patterson AFB OH, 15 April 1988.

4. Andrews, Ralph, Program Manager. Personal interview. F-16 SPO, Wright-Patterson AFB OH, 15 April 1988.

5. Antony, Ron, Program Manager. Personal interview. F-15E SPO, Wright-Patterson AFB OH, 15 April 1988.

6. Bachmann, 1Lt. Steve, Reliability and Cost Program Manager. Personal interview. F-16 SPO, Wright-Patterson AFB OH, 4 March 1988.

7. Booher, Margaret, General Engineer. Personal interview. AFALC/ER, Wright-Patterson AFB OH, 15 April 1988.

8. Britton, George, Chief Engineer. Personal interview. PRAM Program Office, Wright-Patterson AFB OH, 2 March 1988.

9. Burk, Dale, V., Data Base Manager. Personal interview. AFCOLR, Wright-Patterson AFB OH, 19 April 1988.

10. Caudill, Capt. Sue, R&M 2000 Program Manager. Telephone interview. SM-ALC/MMEA, McClellan AFB CA, 25 April 1988.

11. Chatfield. Joe, Deputy Division Chief. Personel interview. RAMTIP Program Office, Wright-Patterson AFB OH, 2 March 1988.

12. Crane, Jerry, Deputy Assistant to the Commander on R&M. Telephone interview. AFLC/MM-R, Wright-Patterson AFB OH, 27 April 1988.

13. Del-Real, Capt. Edward, Structural Engineer. Telephone interview. HQ. MAC/LGMW, Scott AFB IL, 20 April 1988.

14. Edwards, Jerry, R&M Engineer. Personal interview. F-15E SPO, Wright-Patterson AFB OH, 15 April 1988.

15. Forsythe, Alvin, Staff Engineer. Telephone interview. AFLC/MMTQR, Wright-Patterson AFB OH, 27 April 1988.

16. Gomez, David, Aerospace Engineer. Personal interview. AFCOLR, Wright-Patterson AFB OH, 15 April 1988.

17. Hicks, Maj., Keith, F-16 System Control Officer. Telephone interview. AFLC/LOC-TLWC, Wright-Patterson AFB OH, 25 April 1988.

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19. Latterman, Maj., Donald, Deputy Special Assistant for R&M. Telephone interview. OO-ALC/MM-1, Hill AFB UT, 25 April 1988.

20. Pauly, Capt., J. D., Logistic R&M Engineer. Telephone interview. HQ MAC/LGR, Scott AFB IL, 25 April 1988.

21. Quinn, Mike, R&M Engineer. Personal interview. F-16 SPO, Wright-Patterson AFB OH, 4 March 1988.

22. Schneider, Capt., Dean, Reliability Engineer. Telephone interview. SA-ALC/MM-1, Kelly AFB TX, 25 April 1988.

23. Sheperd, Capt., Kathleen, R&M Program Manager. Telephone interview. HQ TAC/SMO/R&M, Langley AFB VA, 21 April 1988.

24. Smith, Maj., Chief Production and Deployment Division. Personal interview. F-15E SPO, Wright-Patterson AFB OH, 15 April 1988.

25. St.Pierre, SMsgt., Steve, F-16 Avionic Field Support Manager. Personal interview. F-16 SPO, Wright-Patterson AFB OH, 4 March 1988.

26. Tirpack, John, Deputy Division Chief. Personal interview. PRAM Program Office, Wright-Patterson AFB OH, 4 March 1988.

27. Vincent, Ken, Program Manager. Personal interview. PRAM Program Office, Wright-Patterson AFB OH, 2 March 1988.

28. Whisler, Don, Falcon C Program Manager. Personal interview. F-16 SPO, Wright-Patterson AFB OH, 15 April 1988.

29. Willeck, Maj., Dennis G., Assistant DPML. Personal interview. F-15E SPO, Wright-Patterson AFB OH, 18 April 1988.

30. Williams, MSgt., John, Superintendent. of Maintenance in R&M. Telephone interview. HQ TAC/SMO/R&M, Langley AFB VA, 21 April 1988.

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This thesis outlines methodologies used to identify reliability and maintainability problems in fielded Air Force weapon systems. The goal of the thesis was to provide program managers new to the R&M field an understanding of the terms, procedures, and organizations in the Air Force related to solving R&M problems in fielded weapon systems.

The study examines the process of gathering data, selecting and prioritizing a list of candidate projects, and the justifying of these projects to upper management for approval to implement as an R&M improvement. It also examines the use of product improvement working groups (PIWGs), and provides examples of successful R&M programs, and the benefits that can be achieved with R&M improvements to fielded weapon systems.